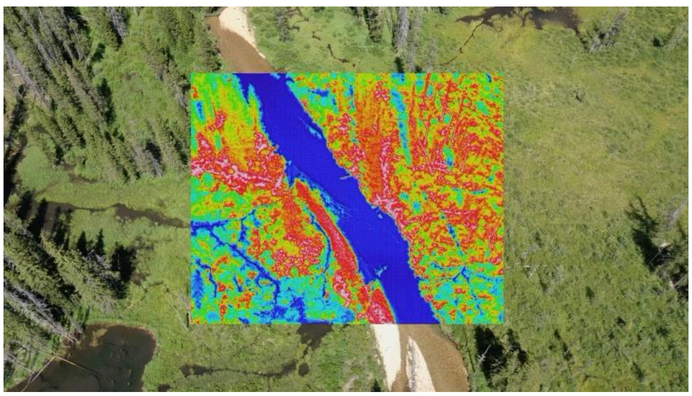
Lab 11: Thermal Infrared Mapping Lab

Thermal infrared (TIR) imaging is a powerful technology for understanding ecosystem processes and sustainable agricultural systems. TIR sensors are becoming increasingly common on drones, and the applications of TIR images are increasing. Single TIR photos or TIR videos can be invaluable for infrastructure inspections or in search-and-rescue operations. However, in agriculture and natural resources, the power of TIR data comes when multiple photos can be combined into orthomosaics of large fields or landscapes.

However, TIR imagery has some unique traits that can make it challenging to work with it in photogrammetry applications. For example, TIR sensors are usually much lower resolution and have a smaller sensor size (and hence, smaller image footprint on the ground) than similar RGB or multispectral imagery (see figure below). TIR imagery also lacks a lot of image detail compared to RGB or multispectral imagery. For these (and other) reasons, aligning TIR images in photogrammetry software can be difficult.



Difference in image extent for thermal and RGB camera on the Autel Evo II Dual drone

Objectives

In this lab, we will work through import, alignment, and creation of TIR orthomosaics. The main objectives of this lab exercise are to familiarize students with:

- File formats used for TIR imagery
- Processes for importing and aligning TIR images in Metashape
- Creation of TIR orthomosaics
- Raster transformations for converting image DNs to temperature values

Deliverables

Fill out and submit the questions in the lab questions document.

Note: Please refer to the class Canvas site for lab due dates. You may work together and help each other, but please make sure what you turn in is your own work.

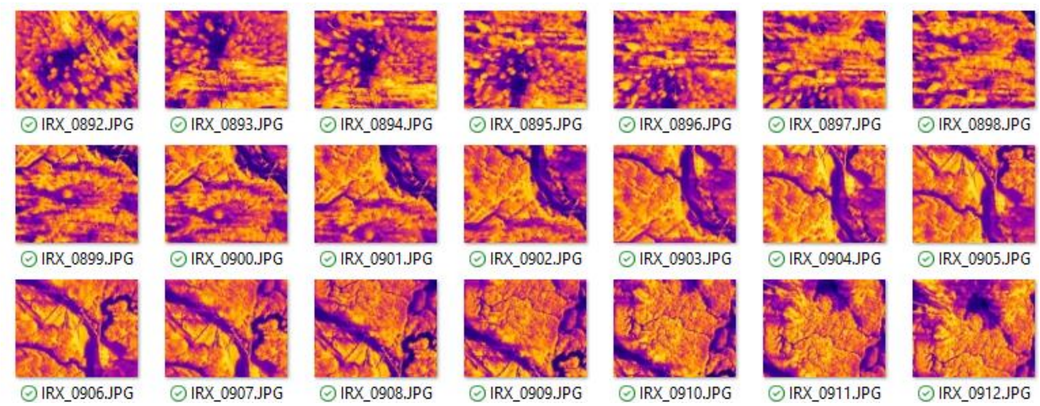
Lab Datasets

In this lab, we will use a TIR image set collected for a stream and beaver-dam complex in central Idaho. These images were collected in 2023 with an Autel Evo II Duo 640T drone with a FLIR Boson radiometrically-calibrated TIR sensor.

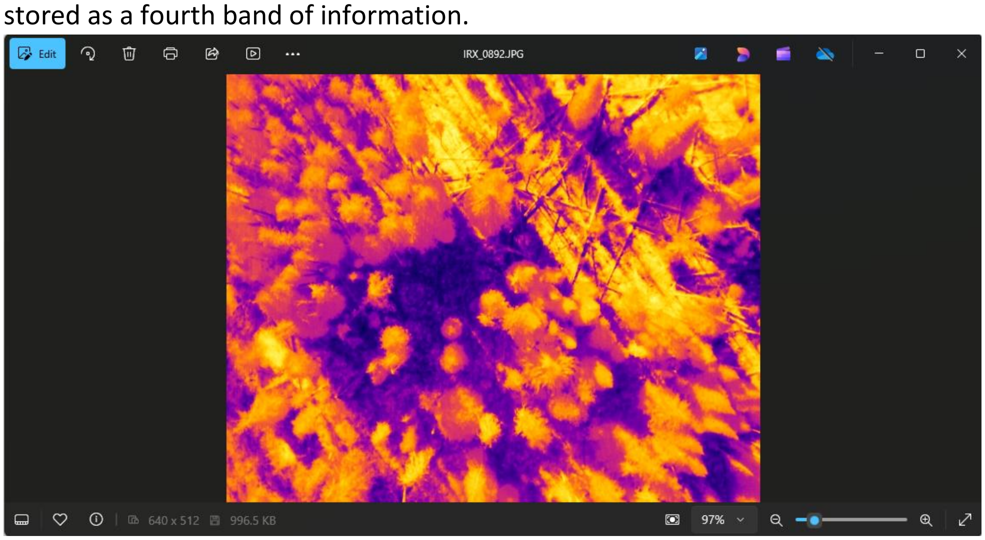
Section 1. TIR Image Formats

TIR imagery can be stored in several different formats. Non-radiometrically calibrated TIR sensors will typically store images as simple JPEG files with the colors representing different relative temperatures (i.e., the temperature values themselves are not stored, just their representation on the color palette). This can make images from non-radiometrically calibrated sensors challenging to work with for photogrammetric applications.

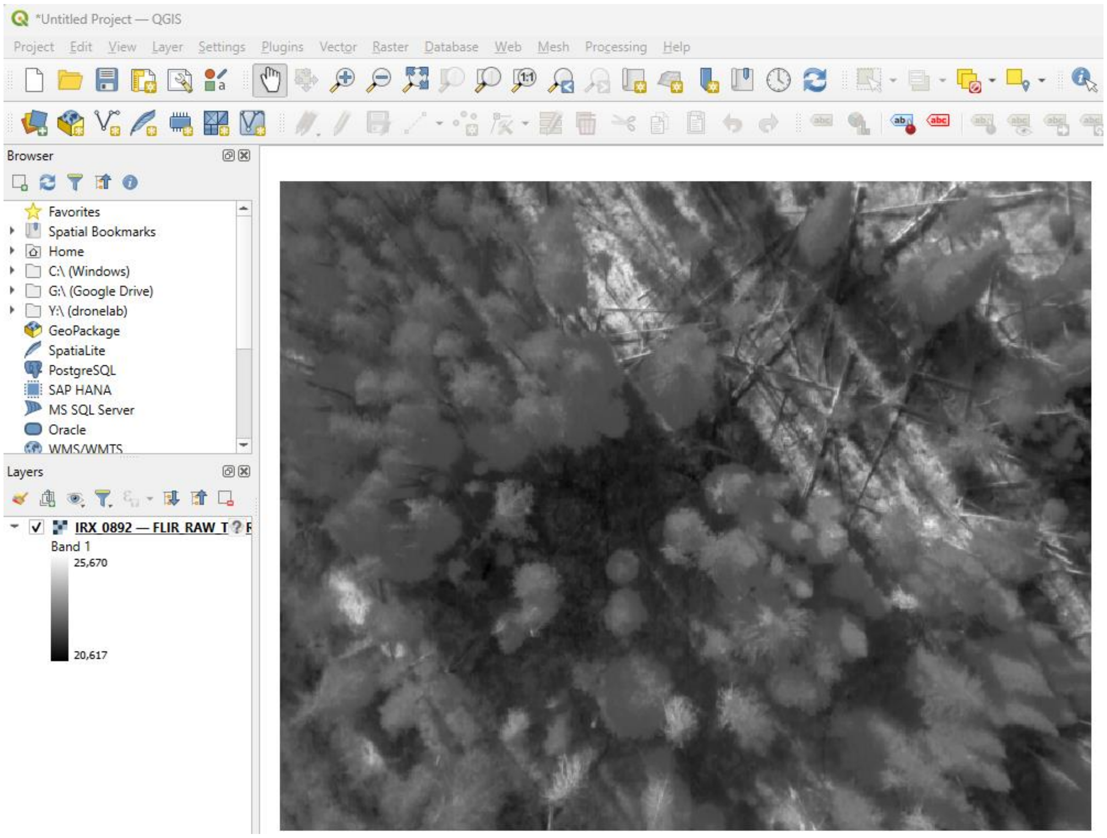
Radiometric TIR imagery is usually stored either as TIF files or in a Radiometric JPEG (R-JPEG or sometimes JPEG-R) format. The images from the Autel Evo II Duo drone are in this R-JPEG format. When you look at the image files in a file manager (e.g., Windows Explorer), they appear to be normal JPEG files.



You can even open one of these photos in an image viewing application (e.g., Microsoft Photos) and they will look just like any other JPEG. The color palette used by the drone at the time of image capture is stored in the three (Red, Green, Blue) color bands of the JPEG, but the actual TIR digital values are stored as a fourth band of information.



If you open one of the R-JPEG files in an application that is capable of seeing and displaying the 4th image band (e.g., QGIS, ArcGIS/ArcPro, R with the Thermimage package), you can see the actual temperature data.



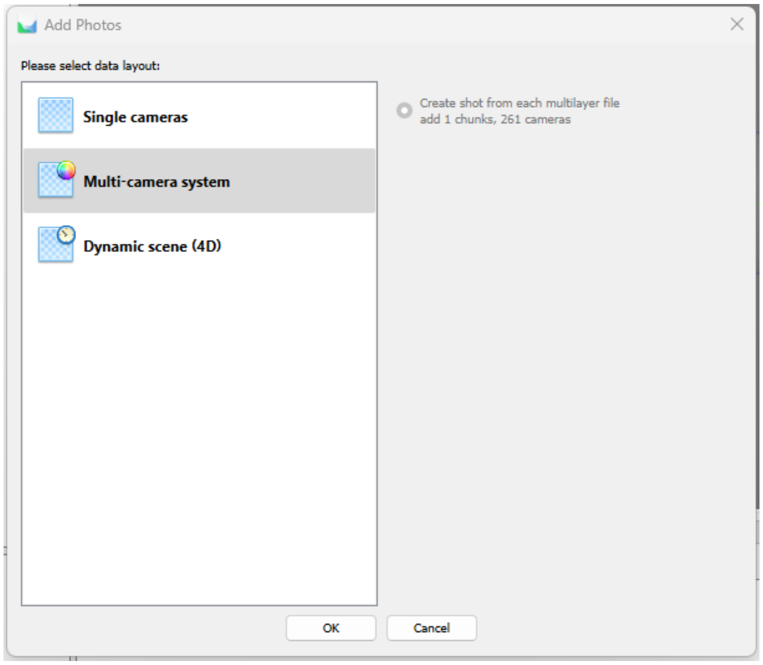
For photogrammetric processing of the images, we need: 1) R-JPEG images that record the actual TIR or temperature values, and 2) a photogrammetric application (like Metashape!) that can recognize R-JPEG formats and import the temperature/TIR layer.

Section 1: Importing and aligning TIR imagery

The first steps in working with TIR imagery in Metashape is to get them imported correctly and aligned.

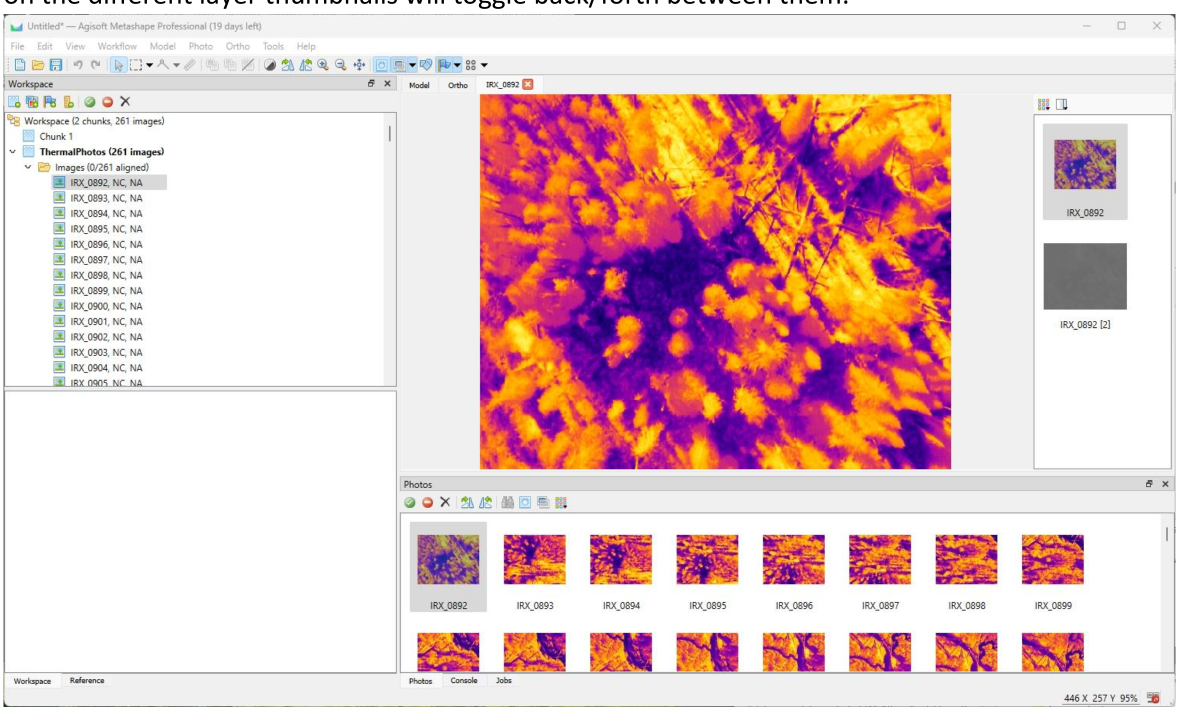
1. Start a new Metashape project and import the folder with the TIR images (from the main menu, Workflow -> Add Folder).

2. Metashape will detect the extra band with the TIR/temperature data in the R-JPEG files and ask how you want to add the photos. Select Multi-camera system and click OK.



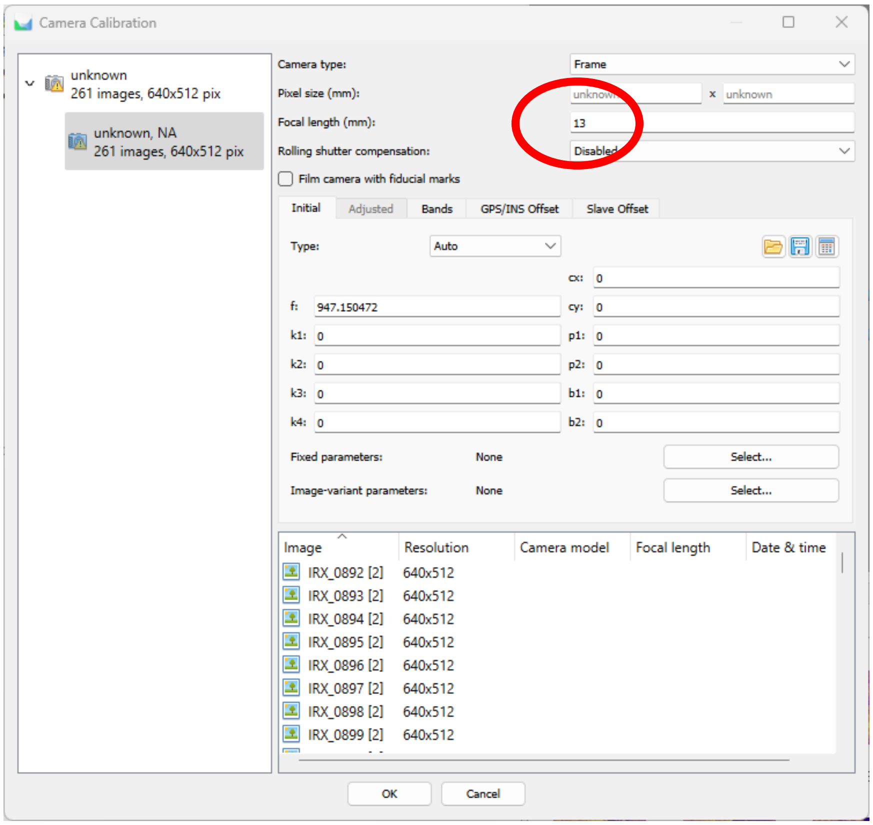
Note: if you bring in the photos as single-cameras, Metashape will bring in each photos twice – once for the JPEG color version of the photo, and a second time for the TIR band. You can still process them this way, but it's cleaner/easier to import them as multi-cameras.

3. Explore the photos you have imported. From the photo tray, double-click on a photo to open it. Notice that there is a new/extra pane on the right-hand side of the photo window that showed the color version of the photo and a gray version (which is the temperature/TIR layer). Clicking on the different layer thumbnails will toggle back/forth between them.

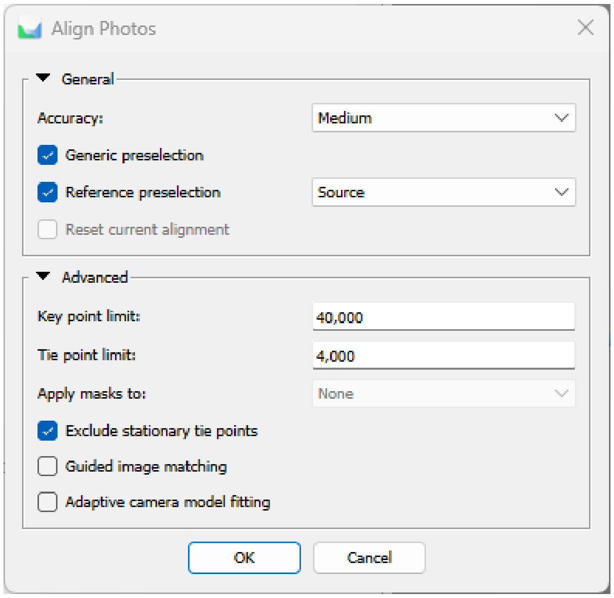


4. Photogrammetric applications like Metashape can sometimes have issues estimating camera interior orientation parameters like focal length from TIR images. This can result in difficulty aligning photos. One way to help with this is to tell Metashape what the camera focal length is.

   From the main menu, select Tools -> Camera Calibration. There will be two cameras listed, one for the RGB version of the photo, and the second for the TIR band. **Set the focal length for both cameras to 13mm** (focal length of the Autel Evo II Duo 640T's thermal camera). Click OK when done.

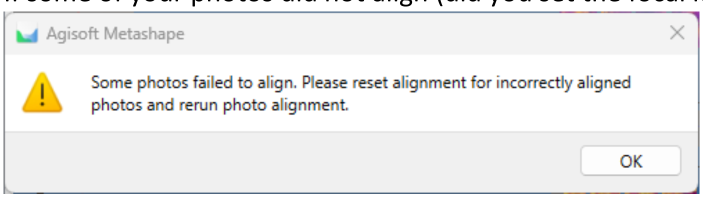


5. Align the photos. From the main menu, select Workflow, Align Photos. Choose Medium accuracy and leave the other options as default.



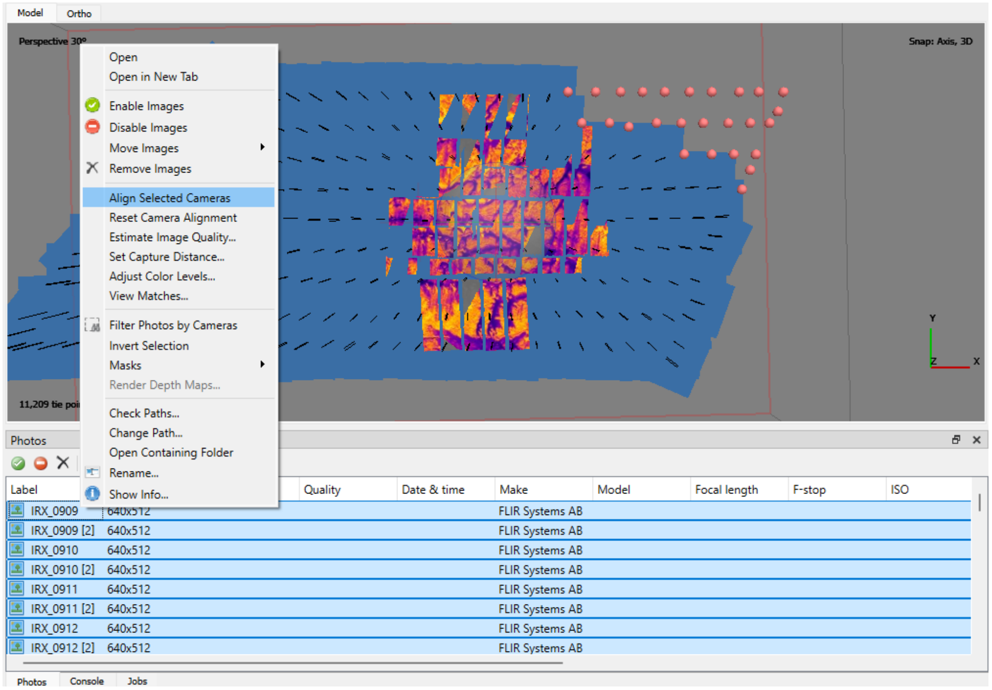
Note: TIR images are much lower resolution than other image sets we've used so far. Accordingly, the alignment will be much quicker than you may have experienced before.

If some of your photos did not align (did you set the focal length??):



a. Unaligned photos will show up as dots whereas aligned photos will show the photo orientation in the model window.
b. Select a set of unaligned photos in the model window or in the photo tray.

c. Right-click on the selected photos in the photo tray and choose **Align Selected Cameras**.



d. This ***<u>should</u>*** align the photos.

e. If all the photos do not align at one time, select a set adjacent to aligned photos and try to align them. Then select the next set of unaligned photos and repeat until you have all the photos aligned (or as many as will align)

f. Perform a camera optimization (magic wand button on the reference pane toolbar) when you have all the cameras aligned.

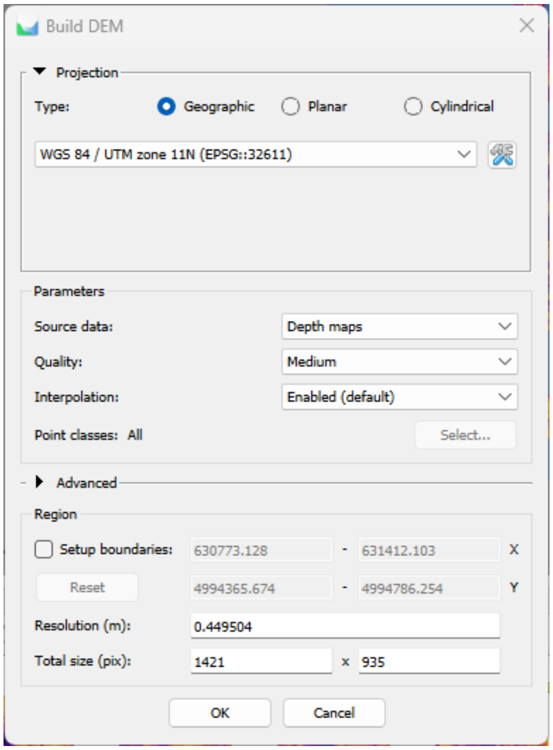
6. Perform any optimization of the sparse model you want/need to do. *Note: TIR photogrammetric models, because the photos are low resolution, will have many fewer tie points than we are used to seeing. Be very cautious about removing too many tie points.*

Section 2: Building TIR Orthomosaics

Now that we have our photos aligned, we can build the orthomosaic. We can do the normal process of building a dense cloud and then the DEM, but dense point cloud is not that helpful from TIR data (because of the low resolution of TIR photos). So, we can build the DEM straight from depth maps calculated from the photo alignment and the 3D model, and then use it to create the orthomosaic.

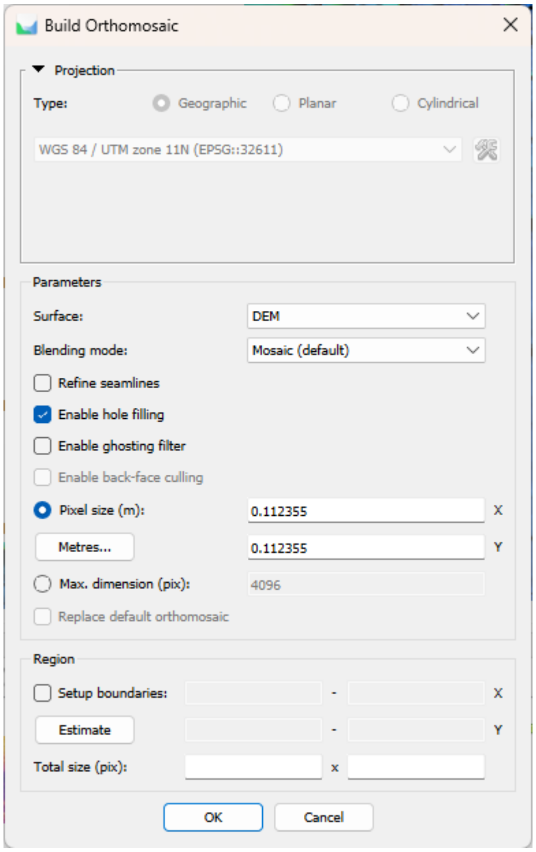
7. From the main menu, select Workflow -> Build DEM.

8. Select a projected coordinate system (UTM Zone 11N, EPSG::32611), and set the source data option to Depth maps. Leave the other settings as default, and click OK.



Note: it will take longer than usual to create the DEM because Metashape must first calculate the depth maps (which normally happens during the creation of the dense point cloud).

9. Finally, build the orthomosaic. From the main toolbar, select Workflow -> Build Orthomosaic. Make sure the surface is set to DEM. Leave the other options as default and click OK.



10. Spend some time panning and zooming around to look at the orthomosaic.

Section 3: Converting TIR image values to temperature

The orthomosaic we have created is cool, but it is still showing us the original JPEG colors (not the TIR values), and the TIR values are in image DN's, not temperature units. We can use a raster transform in Metashape to fix this.

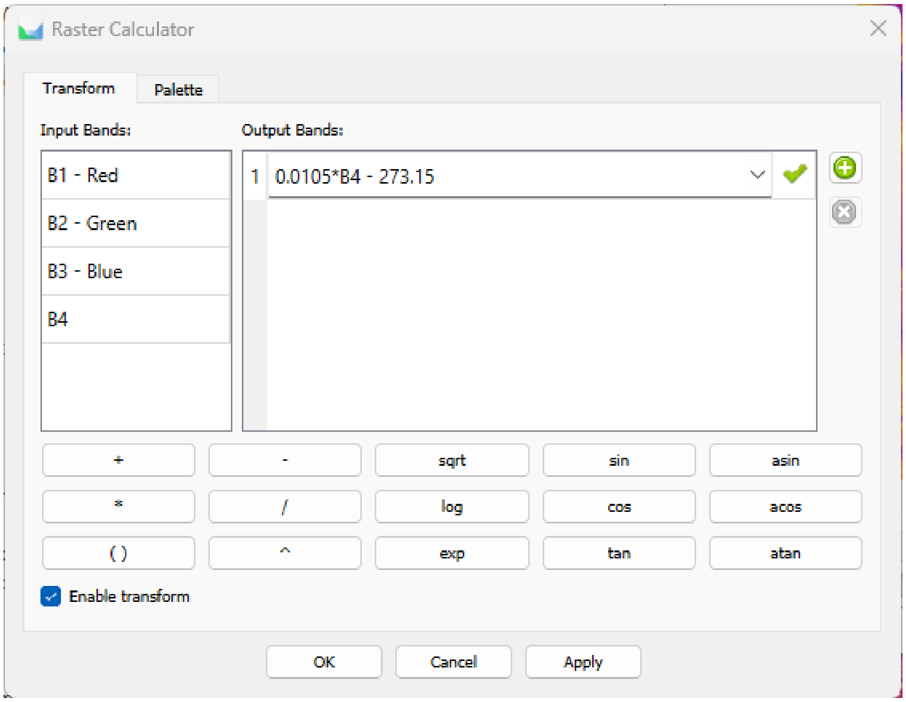
11. Right-click on the orthomosaic and choose Duplicate.

12. Rename the copy of the orthomosaic to "Temperature".

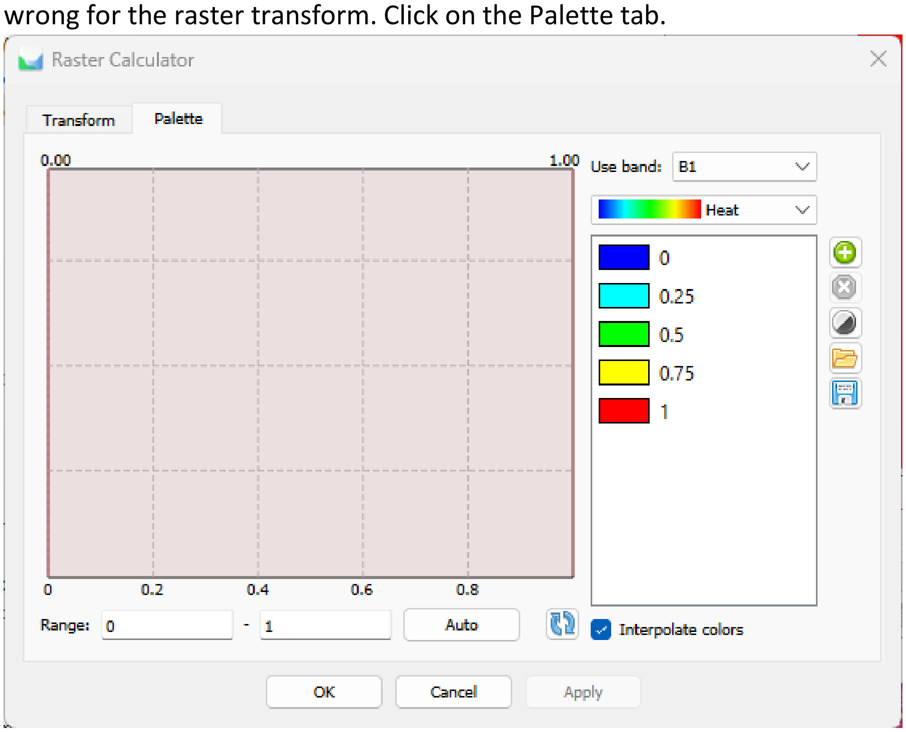
13. From the main menu select Tools -> Set Raster Transform.

    The FLIR Boson sensor on the Autel Evo II Duo records temperature values in degrees Kelvin times 100. So, we can convert the TIR image values to temperature (in degrees C) by multiplying the band values by 0.01 and subtracting 273.15 (difference between Celsius and Kelvin temperature scales). However, the calibration of the Boson sensor isn't perfect, so some adjustment to the transformation is needed to meet local conditions. For this area, we determined that a coefficient of 0.0105 gave plausible temperature measurements for most areas.

14. Create a raster transform to be: 0.0105*B4-273.15. Band 4 (B4) is the TIR data band. Make sure "Enable Transform" is checked and click Apply.

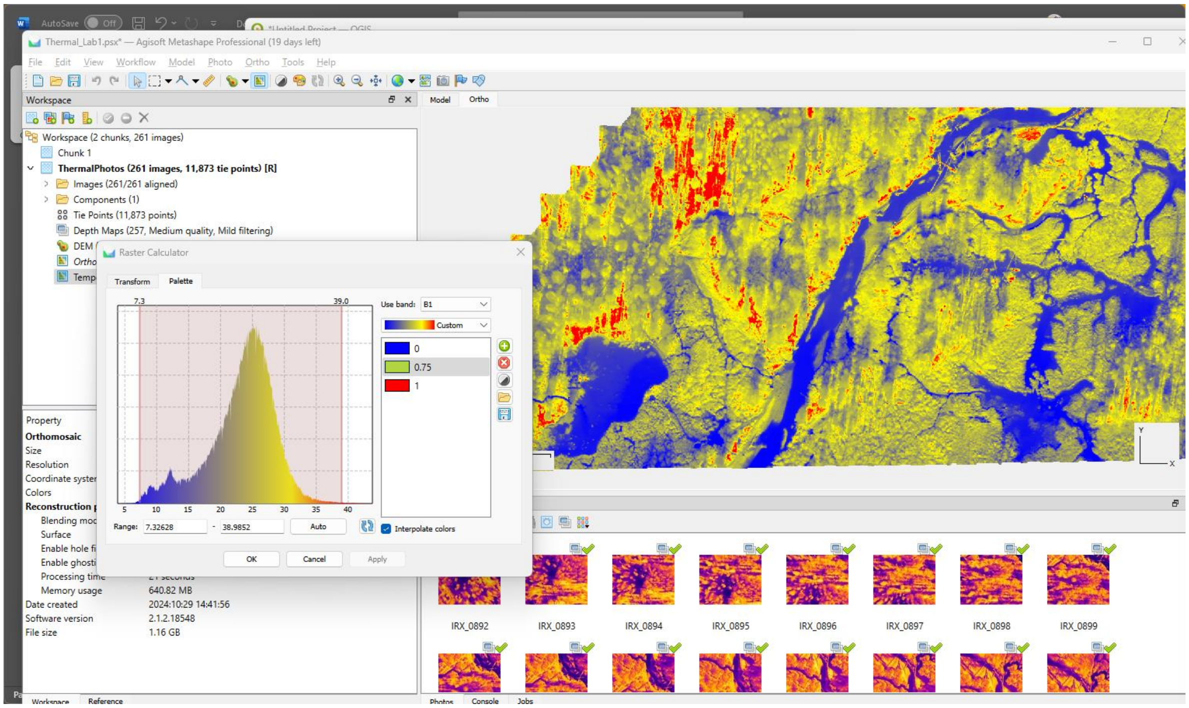


15. You may have noticed that the ortho map turned all one color! That's because the color-ramp is wrong for the raster transform. Click on the Palette tab.

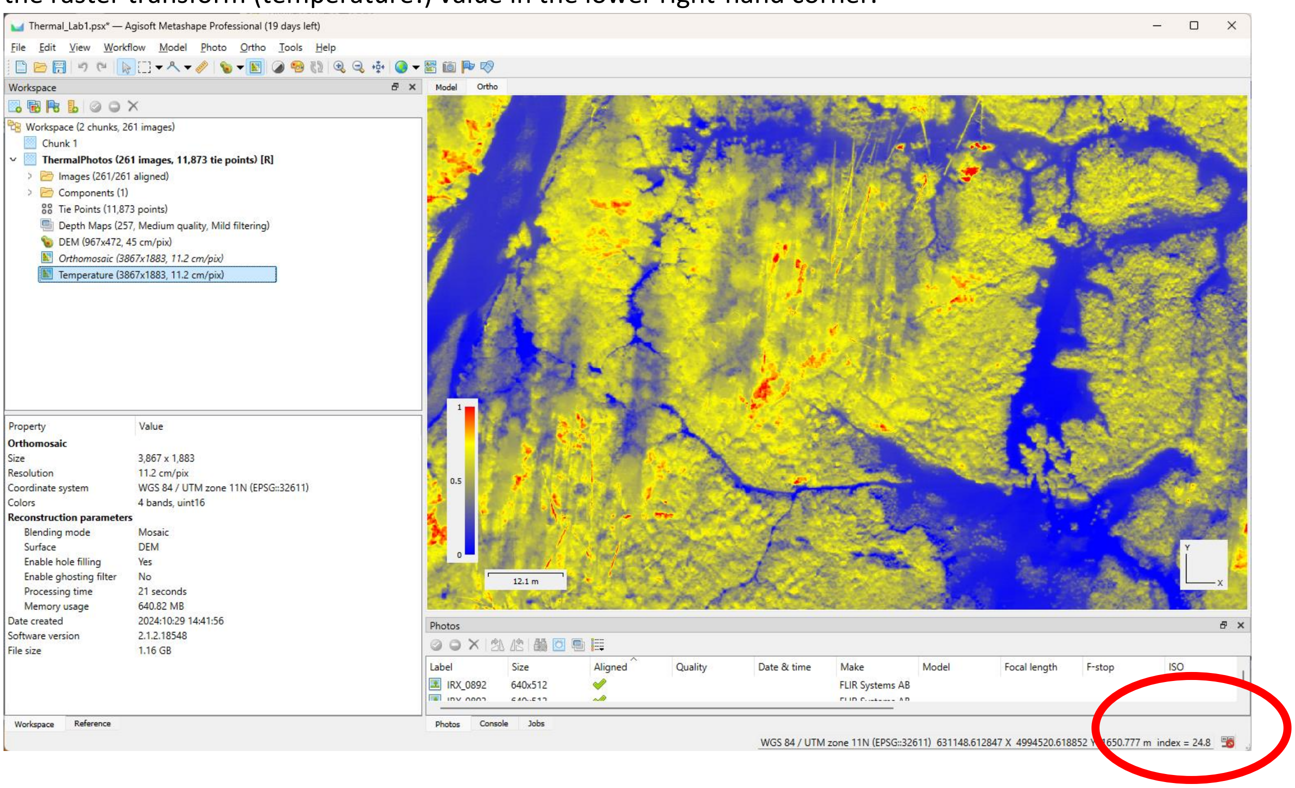


16. Click the refresh (recycle) button, to reset the scale to the temperature values, then click Auto to adjust the color ramp. You can play around with different color ramp options or colors (I

prefer three color ramps). Click OK when you're done to save the color ramp.



17. Notice now that when you move your mouse cursor over the map that Metashape is displaying the raster transform (temperature!) value in the lower right-hand corner.



18. Spend some time looking at temperature values for various landscape features. Toggle back and forth on the temperature and the RGB orthomosaic to examine what kinds of features might be giving high or low temperature values.

IT WOULD BE A *REALLY* GOOD IDEA TO SAVE YOUR PROJECT *BEFORE* YOU CLOSE METASHAPE.

That's it for this lab! When you are finished, fill out the Lab question sheet and submit it on Canvas.