Thermal Mapping of Wedgemount Glacier

Aaron ROOKE, David BORJA and Eric SACZUK, Canada

Key words: photogrammetry, remote sensing, thermal orthomosaic, young surveyor

SUMMARY

An aerial survey was conducted at Wedgemount Glacier in British Columbia, Canada using a DJI Mavic 2 Enterprise Dual. Both visual and thermal images were captured. A dense point cloud and orthomosaic were created using the visual images. These were used to make comparisons with previous GNSS surveys. The glacier was found to have receded a by a large amount. Thermal and visual images were combined on-the-fly using the DJI MSX function. These were used to create a thermal orthomosaic of the glacier. Radiometric temperature data is not stored in the images by the UAV. Attempts were therefore made to create a temperature legend for the thermal orthomosaic, however, these procedures were not successful. Recommendations were made to better carry out this process for future studies.

Thermal Mapping of Wedgemount Glacier

Aaron ROOKE, David BORJA and Eric SACZUK, Canada

1. INTRODUCTION

1.1 Background

Global warming has accelerated the process of glacial melting which directly affects the communities that depend on them as sources of water. Currently, glacier studies track the movement of the glaciers, the rate at which glaciers melt and changes in glacial thickness from season to season. These studies have normally been carried out using satellite imagery.

In recent years, unmanned aerial vehicles (UAVs) have emerged as an alternative to using satellite imagery for glacial studies. The current project took advantage of UAV technology to obtain data at Wedgemount Glacier (figure 1) in British Columbia, Canada. Wedgemount Glacier was selected as it had previously been surveyed by BCIT faculty and students. Thermal imagery was also captured with the UAV. Thermal imagery can be an important source of information for glacier scientists because it helps them determine how glacier debris cover affects melt rate.

Figure 1: Toe of Wedgemount Glacier

1.2 Objectives

The current study had two primary objectives:

1. The first objective was to use UAV mapping procedures to determine the amount of glacial recession with respect to previous years. The aim was to establish horizontal changes in the position of the glacier as well as to calculate the overall loss in volume for the toe of the glacier. This is relatively straightforward with well-established procedures and software.
2. The second objective was to create a thermal orthomosaic of the glacier along with a temperature legend, which could be used to map the temperature on the glacier. This procedure is less well-established and presents more challenges.

The goal was to carry out these procedures with a readily available, off-the-shelf UAV and industry standard software.

1.3 Thermal orthomosaic

Creating a thermal orthomosaic is problematic for several reasons. First, thermal images have much lower resolution than visual images. While consumer grade visual light cameras typically have a resolution of at least 12 MP, a higher-end thermal camera used for UAVs might have a resolution of 0.33 MP (640 x 512 pixels) (Maes et al, 2017) (Lovas and Molnar, 2018). Second, they have a smaller focal length than RGB cameras (Javan and Savadkouhi, 2019). Third, thermal images contain less geometric information. This is especially true if there is not a prominent temperature gradient within the thermal images. A varying thermal profile is necessary to establish matching points between overlapping images. Overall, these factors can result in 3D models with low spatial resolution (e.g. buildings with soft edges) (Javan and Savadkouhi, 2019) (Clarkson et al, 2017).

Several approaches have been put forward to resolve these issues, most of which involve the use of accompanying visual images. One approach is to improve thermal image positions using the information obtained in visual images (Maes et al, 2017). Another approach is to create visual and thermal point clouds separately, then register them and densify the thermal point cloud using the visual point cloud (Javan and Savadkouhi, 2019). Another is to combine the visual and thermal images before proceeding to subsequent steps (Lovas and Molnar, 2018). Techniques to improve thermal 3D models and orthomosaic that do not involve the use of accompanying visual images are ensuring that the thermal camera is well-calibrated (Maes et al, 2017) (Khodaei et al, 2015) as well as making rigorous atmospheric corrections (Maes et al, 2017).

These methods have often involved custom made or modified UAVs, along with manually programmed data processing routines. These procedures can be complicated and are not easily replicated. As stated earlier, the goal of the current study is to attempt to create a thermal orthomosaic using an off-the-shelf UAV along with industry standard software. The UAV chosen was the DJI Mavic 2 Enterprise Dual (M2ED), while the software used was Agisoft Metashape Professional.

The M2ED has a function called MSX (Multi-Spectral Dynamic Imaging) which adds visible light details to the thermal imagery in real-time. The thermal and RGB data are combined on the fly. This results in a hybrid MSX image (figure 2) which contains thermal information, while at the same time taking the advantage of the higher resolution and differentiating features of visual images. This was the method chosen to combine visual and thermal imagery to aid in the process of creating an orthomosaic.

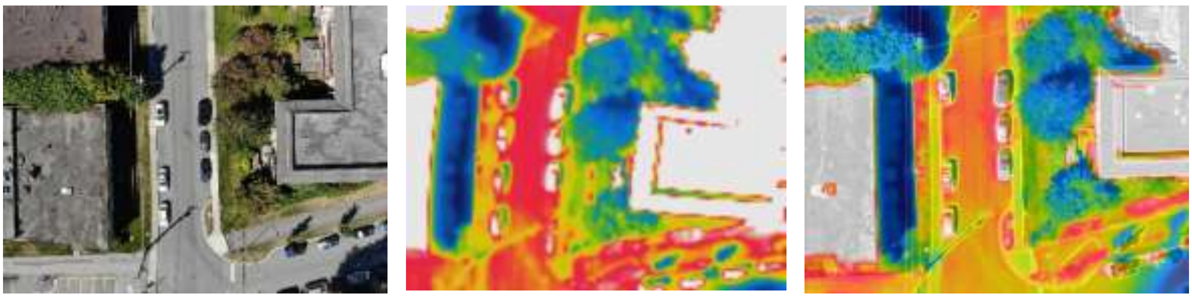

Figure 2: visual, thermal, and MSX images

One disadvantage of the M2ED is that at the time the current study was conducted, it was not capable of capturing radiometric temperature data. Other thermal cameras store thermal images in the R-JPEG format, which preserves the temperatures observed at the time of image capture. The M2ED captures thermal (or MSX) images in the JPEG format. This means that the temperature readings at the time of observation are lost.

In addition, the functions that determine thermal color palettes used by the M2ED are not readily available to the public. As a result, to determine the temperature at specific locations in the image, the color palette used by DJI and the functions that dictate them needed to be recreated. Having the functions for these color palettes, as well as the temperature range specified during the flight, would allow for temperatures at specific locations on the thermal orthomosaic to be determined using the RGB color combination at that location. Based on this, a temperature legend could be created to allow the thermal orthomosaic to be analyzed. The color palettes used by the Zenmuse XT, a higher end DJI thermal camera, can be seen in figure 3 (DJI, 2019).

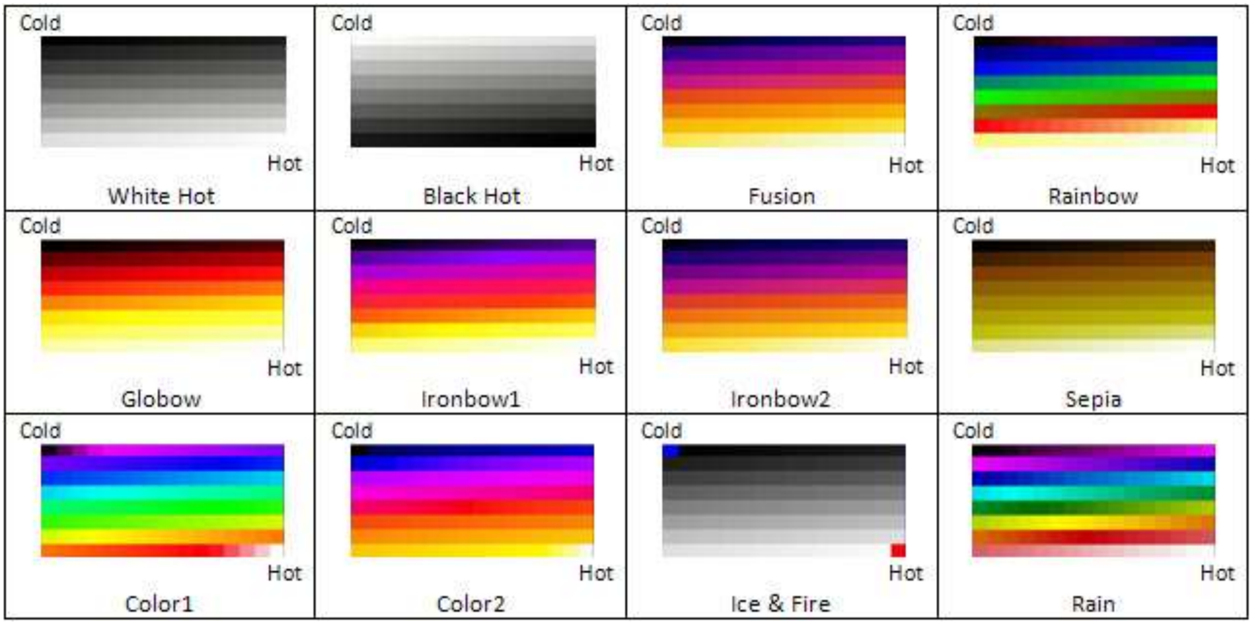

Figure 3: Zenmuse XT thermal camera

3. EQUIPMENT

The UAV used was M2ED (figure 4). It has integrated visual and thermal cameras, which sit side by side on the same gimble. Images are captured simultaneously. The specifications for the M2ED can be seen in the table 1.

Table 1: M2ED Specifications

Thermal Camera	
Sensor Resolution	160x120
Image size	640-480
Accuracy	High Gain: Max ±5% (typical) Low Gain: Max ±10% (typical)
Visual Camera	
Sensor	1/2.3” CMOS, 12M pixels
Lens	FOV: approx. 85° 35 mm format equivalent:24 mm Aperture: f/2.8
Image size	4056x3040

Figure 4: Mavic 2 Enterprise Dual

An infrared thermometer was used to record ground temperatures. The model used was the Maximum 057-4632-8. The precision is ±2°C or 2% of the reading, whichever is greater.

GNSS Equipment was used to set up ground control targets and record the location of ground temperatures measurements that were taken with the infrared thermometer. A Trimble R8 was used as a base station, while a Trimble R10 was used as the rover.

4. DATA ACQUISITION

4.1 GNSS survey and ground temperature readings

A GNSS base station with good visibility of the site was set up. An approximate position was established and used to send corrections to the rover, which operated in RTK mode. The base station also collected static data throughout the course of the survey. Ground control points (GCPs) were placed on the glacier surface and surrounding areas. Their coordinates were measured using the rover. Ground thermal readings were then obtained using the infrared thermometer. GNSS observations were also taken at various locations throughout the glacier and the surrounding area as checks to the UAV data.

4.2 Aerial survey

Once the targets were set up, the UAV was flown and thermal and visual images were captured. The flights were conducted at roughly the same time as the ground temperature recordings were being captured to ensure that the temperature conditions would be the same for the infrared thermometer and the UAV thermal camera. The images used to create the thermal orthomosaic were captured over the course of three flights taking approximately two hours. A greater area was flown the following day to increase the size of the visual orthomosaic. The flying altitude and image overlap were changed from one flight to the next to accommodate the varying elevation of the terrain.

The M2ED has different color palettes available to represent the gradient of temperatures being recorded. The rainbow color palette was chosen for its visual appeal. A temperature range must also be selected. Temperatures within this range appear along the spectrum of the color palette in the MSX images, while temperatures outside the range appear as greyscale. The temperature range chosen was -4°C to +4°C. This narrow range was chosen to discriminate between different areas of the relatively stable temperature gradient of the glacier. Other details of the flight can be seen in the table 2.

Table 2: Thermal Flight Details

Flight No.	Start Time (PST)	End Time (PST)	Altitude (m)	Overlap (front/side)	Speed (m/s)	GSD (cm/pix)
1	15:40	16:00	120	85/85	5	3.67
2	16:10	16:30	120	85/85	5	3.67
3	17:15	17:35	80	70/80	5	2.45

5. DATA PROCESSING

5.1 GNSS

The most recent survey of the glacier that formed the basis of the comparisons was a topographic survey conducted in 2012 with GNSS equipment. The horizontal and vertical datums used in the 2012 survey were NAD83(CSRS) and CGVD28, respectively. The base station was adjusted using the Whistler Canadian Active Control System (CACS) station using the datums of the 2012 survey in Trimble Business Centre (TBC). The points collected with the rover, including the GCPs, were then shifted according to the adjusted base station position.

5.2 Visual orthomosaic and glacier recession

The visual images were processed in Agisoft along with the adjusted GCPs. A dense cloud, DEM, and orthomosaic (figure 5) were generated. Comparisons for horizontal recession were carried out using the orthomosaic, along with the 2012 points, in Civil 3D. The change in volume determination was carried out in TBC using the dense point cloud and the points from the 2012 survey. A surface was created from each of these and the volume between them was determined.

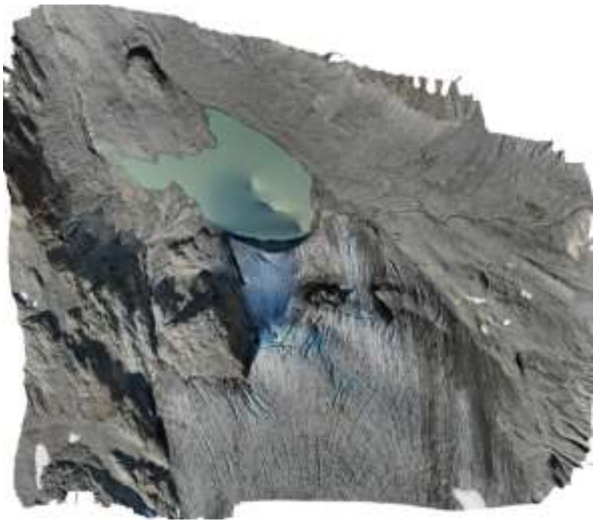

Figure 5: Visual Orthomosaic

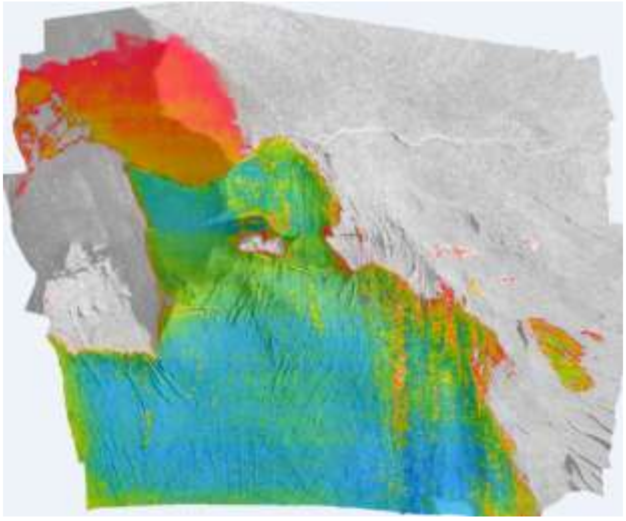

Figure 6: Thermal Orthomosaic

5.3 Thermal orthomosaic

The thermal orthomosaic (figure 6) was generated using Agisoft as well. The MSX images provided enough visual information to allow for proper alignment to occur. Unfortunately, however, the GCPs that were used were not visible in the MSX images. Therefore, the thermal orthomosaic was processed without the use of GCPs. A dense point cloud, DEM and orthomosaic were created in the same manner as the RGB dataset.

5.4 Temperature legend

Two methods were attempted to determine the functions behind the DJI color palette. In both cases, QGIS was used. The first involved associating the infrared thermometer measurements taken on the ground with the RGB values at the same location on the thermal orthomosaic from figure 6. A plot was made in Microsoft Excel comparing the temperature and RGB values to find a pattern. In the second method, two color palettes available online were used in a similar manner to plot RGB values along a scale extending from one end of the color palette to the other. The first color palette is from the DJI Zenmuse XT user manual (DJI, 2019), while the second is the rainbow color palette found on a blog website (Clement, 2019) featuring the M2ED (figure 7). The Microsoft Excel plots for both methods can be seen in figures 8 to 10.

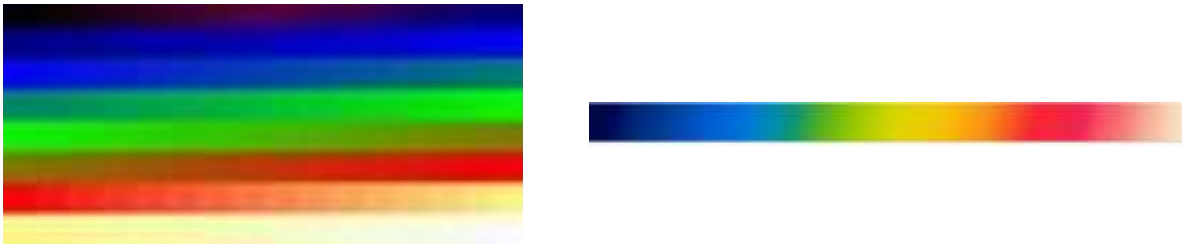

Figure 7: Color Palettes

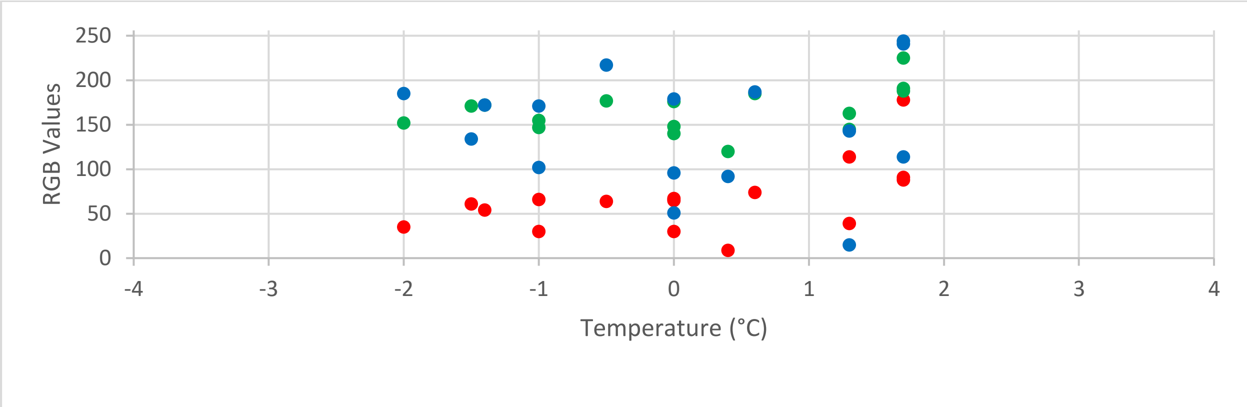

Figure 8: Plot of RGB values from the thermal orthomosaic vs temperature ground readings

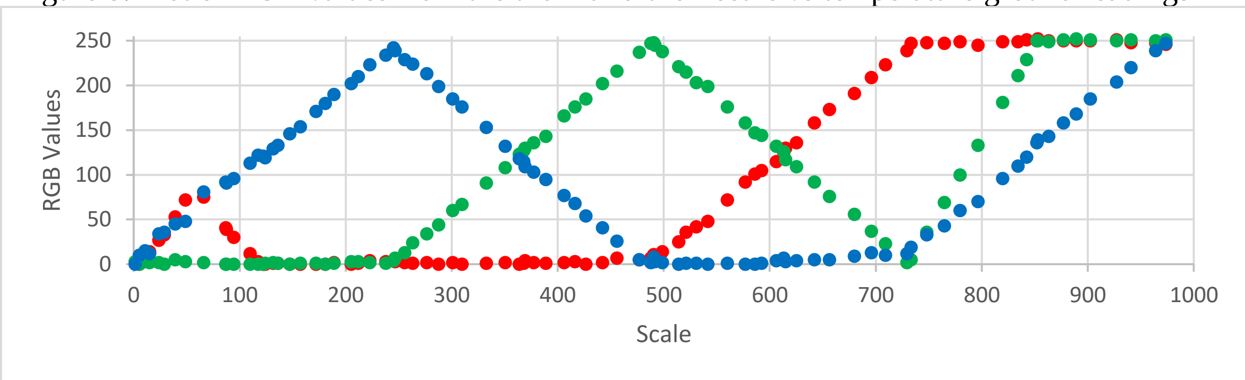

Figure 9: Plot of RGB values from rainbow color palette found in the Zenmuse XT user manual along the scale of the color palette

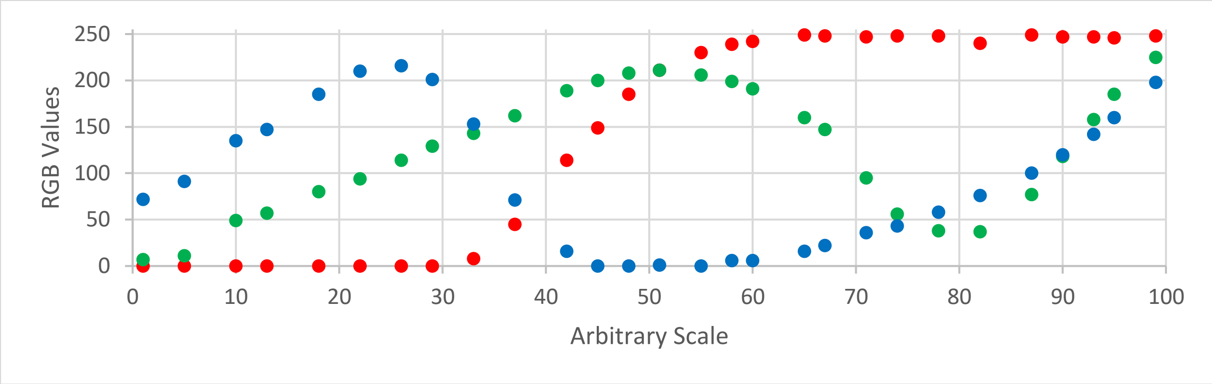

Figure 10: Plot of RGB values from the rainbow color palette found on a blog website along the scale of the color palette

6. RESULTS

6.1 Visual orthomosaic and glacier recession

The glacier was found to have receded by approximately 200 metres horizontally. It was also determined that a volume of approximately 2,000,000 cubic metres was lost in the toe of the glacier.

6.2 Thermal orthomosaic

There were two problems that arose with the thermal orthomosaic. The first was that each MSX image displayed warmer edges than the centre (figure 11). This appeared to roughly match the radial distortion plot from Agisoft Metashape for the thermal camera (figure 12). It is unclear why this occurred. This did not occur in MSX images in other projects where the temperature range was less narrow. This is put forth as a possible reason for the problem.

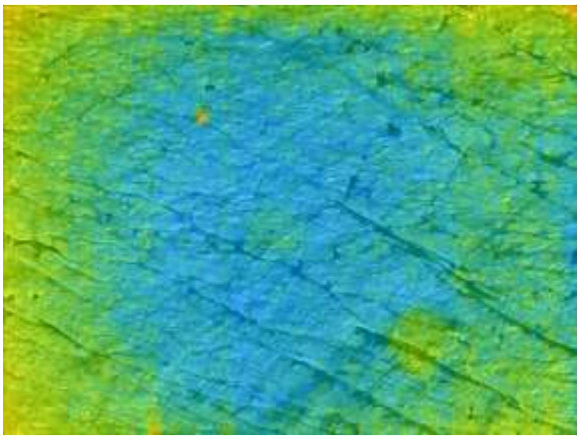
Figure 11: MSX image with warming pattern on edges

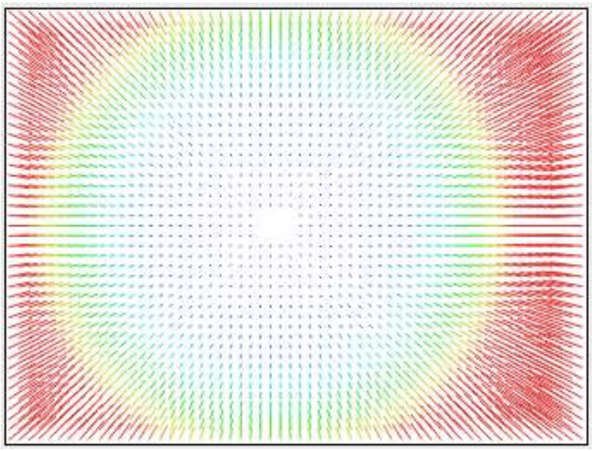
Figure 12: radial distortion from plot

The second problem was that temperature readings were sometimes different from one flight line to the next. This was especially apparent when adjacent flight lines were from different flights. This pattern can be seen in the dense point cloud (figure 13). There is evidence of it in the thermal orthomosaic as well (figure 6).

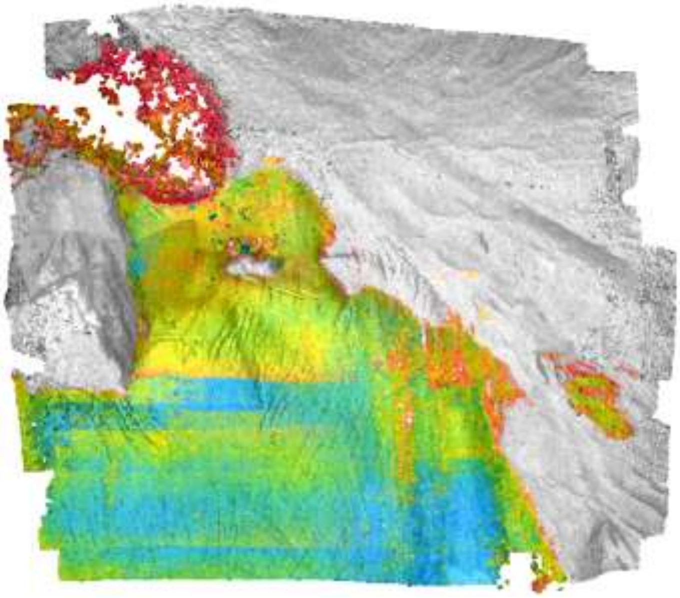

Figure 13: dense point cloud

6.3 Temperature legend

There were a few problems with the MS excel plots generated by the two methods. With the first method, most of the ground temperature measurements were taken on the surface of the glacier, which has a relatively constant temperature. As a result, the sample of temperatures recorded on the ground did not adequately cover the entire temperature range used by the thermal camera for the UAV flights. This can be seen in figure 8, where the temperature range set in the M2ED is -4°C to +4°C, but the range of ground samples is only -2°C to +2°C. There is no readily discernable pattern. In addition, because the GCPs were not used in the thermal orthomosaic, it is unclear whether the locations of the ground temperature measurements accurately matched the location of the features on the thermal orthomosaic. This could result in the incorrect RGB values for a given ground temperature reading. Another potential problem is that if the accuracies of the infrared thermometer and the M2ED thermal camera are considered, the temperature range chosen was may have been too narrow. The differences in RGB values may be largely due to noise, making it difficult to find a pattern.

With the second method, two different patterns emerged based on the two color palettes. It was unclear which, if either, accurately matched the actual color palette used by DJI. When comparing the RGB color combinations on the thermal orthomosaic to RGB color combinations of the two color palettes, neither of them matched. It is possible that this was because the thermal orthomosaic was created using the MSX function, which combines the visual images with the thermal color palette. The RGB color combinations of the color palettes were therefore compared to a pure thermal image captured during a different survey. Again, the RGB color combinations did not match. Therefore, neither of the color palettes analyzed match the actual DJI color palette.

7. CONCLUSION

The comparisons to previous surveys for horizontal recession and volume loss were successful. The glacier was found to have greatly receded. The thermal orthomosaic was successfully created using MSX images as well; however, because of the lack of success in recreating the DJI color palette, temperatures were not able to be reliably associated with specific RGB values of the thermal orthomosaic. This meant that a temperature legend was not able to be created, taking away the primary use of the thermal orthomosaic.

8. RECOMMENDATIONS

8.1 Thermal camera capable of capturing R-JPEG images

The simplest method to overcome some of the problems that arose is to use a thermal camera that captures thermal images in the R-JPEG format, such as the Zenmuse XT. This would remove the need to recreate the DJI color palette. However, this would likely come with a greater cost.

8.2 Dedicated survey to recreate color palette

Another possibility is to conduct a survey dedicated to recreating the thermal color palette used by DJI. Care could be taken to sample a high density of ground temperature measurements and across a wide temperature range as specified in the settings of the UAV. This would result in a more accurate and complete color palette. Furthermore, the process of recreating the color palette would be made easier if a pure thermal orthomosaic were used, rather than an orthomosaic generated from MSX images, which may have altered RGB values because of the influence of the visual images. However, as mentioned earlier, creating an orthomosaic from pure thermal images presents its own challenges because of their lower resolution and lack of distinguishing features. One potentially beneficial procedure could be to use GCPs that have a distinct heat signature. This could allow them to be seen in thermal or MSX images. A GCP covered with a metallic foil could potentially provide this. This would aid in creating a more accurately georeferenced thermal orthomosaic, which is important when comparing ground measurements to specific locations on the thermal orthomosaic.

Further study is needed in this area to find a meaningful solution to creating a useful thermal orthomosaic with an off-the-shelf drone such as the M2ED and industry standard software such as Agisoft.

REFERENCES

Clarkson, G., Luo, S. and Fuentes, R., 2017, Thermal 3D Modelling, 34th International Symposium on Automation and Robotics in Construction, Taipei, Taiwan

Clement, J., 2019l, Johnny Appleseed, [Online]. https://blog.ja-gps.com.au/2019/01/dji-mavic-2-enterprise-dual-best-value-thermal-camera/.

DJI, 2019, Zenmuse XT User Manual, [Online]. https://dl.djicdn.com/downloads/zenmuse_xt/en/Zenmuse_XT_User_Manual_V1.2_en_0708.pdf

Javan, F. D. and Savadkouhi, M., 2019, Thermal 3D Models Enhancement Based on Integration with Visible Imagery, GeoSpatial Conference – Joint Conferences of SMPR and GI Research, Karaj, Iran

Khodaei, B., Samadzadegan, F., Javan, F. D. and Hasani, 2015, H., 3D Surface Generation from Aerial Thermal Imagery, International Conference on Sensors & Models in Remote Sensing & Photogrammetry, Kish Island, Iran

Lovas, I. and Molnar, A., 2018, Orthophoto creation based on low resolution thermal aerial images, , SACI - Symposium on Applied Computational Intelligence and Informatics, Timisoara, Romania

Maes, W. H., Huete, A. R. and Steppe, K., 2017, Optimizing the Processing of UAV-Based Thermal Imagery, Remote Sensing, vol. 9, no. 5, pp. 476-492

BIOGRAPHICAL NOTES

Aaron Rooke and David Borja are students in their final year of the Geomatics Bachelor of Science program at the British Columbia Institute of Technology. Dr. Eric Saczuk has been an instructor at BCIT since 2003 and has extensive experience working in the field of photogrammetry and remote sensing.

CONTACTS

Aaron Rooke (Student)
British Columbia Institute of Technology
3700 Willingdon Ave
Burnaby
Canada
Tel. 1+(604)366-8665
Email: rooke42@gmail.com

David Borja (Student)
British Columbia Institute of Technology
3700 Willingdon Ave
Burnaby
Canada
Tel. 1+(604)761-2495
Email: davidfborja@gmail.com

Dr. Eric Saczuk (Faculty)
British Columbia Institute of Technology
3700 Willingdon Ave
Burnaby
Canada
Tel. 1+(604)-451-7197
Email: Eric_Saczuk@bcit.ca