FOUR-BAND THERMAL MOSAICKING: A NEW METHOD TO PROCESS THERMAL IMAGERY FROM UAV FLIGHT

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OUTLINE

- Background
- Objectives
- Methodology
- Results
- Calibration & Assessment
- Conclusion

BACKGROUND

- Unmanned Aircraft Vehicle (UAV) has become a reliable observing platform for environmental remote sensing applications, including wildfire mapping (Ambrosia, 2011), atmospheric studies (Fladeland, 2011), precision agriculture (Hunt, 2005), etc.
- UAV has unique ability for acquisition of high temporal resolution data at very high spatial resolution.

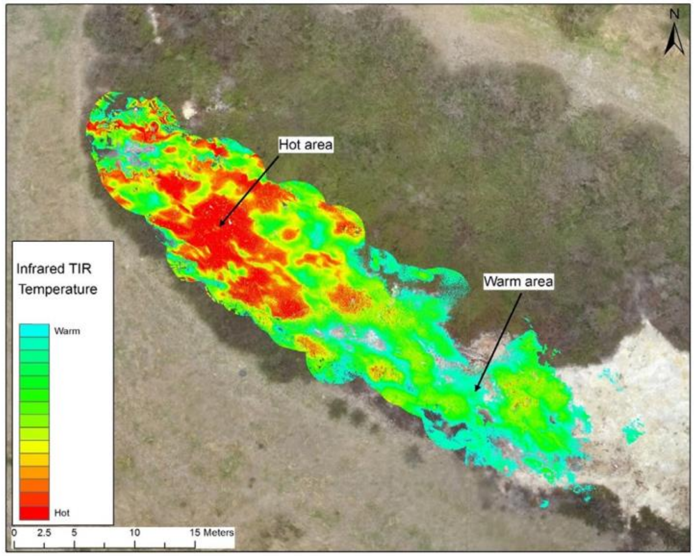
BACKGROUND

- Mosaicking: a technique that can combine or merge multiple images by detecting the features they have in common.
- Mosaicking algorithm: Structure-from-Motion (SfM), from tie points to 3D model then to orthomosaic.
- Mosaicking application: Agisoft Photoscan, Pix4D

BACKGROUND

❑ Chanllenge： thermal mosaicking

Visible band	Thermal band
High resolution	Low resolution
Multi-band contrast	Single-band contrast
Rich texture	Smooth texture
With/without GPS & GCPs	With GPS & GCPs
\	Limited sampled area
Easy to georeference	Hard to georeference



(Nishar, 2016)

OBJECTIVES

- Given the importance of applying thermal imaging technology in local climate change (Coutts, 2016), seismology (Li, 2011), forestry (Nishar, 2016), etc., this project aims to design a new method to process and mosaic thermal images acquired from UAV flight.
- This new method should make up for all the flaws I have mentioned in the traditional workflow.

OBJECTIVES

- ❑ Design a processing workflow to bypass the difficulty of mosaicking single-band thermal imagery.
- ❑ The final product, thermal orthomosaic, should lose no sampled area as opposed to the visible orthomosaic.
- ❑ Figure out how to calibrate the temperature map and then validate the calibration.

METHODOLOGY

1. Overview: Four-band Thermal Mosaicking

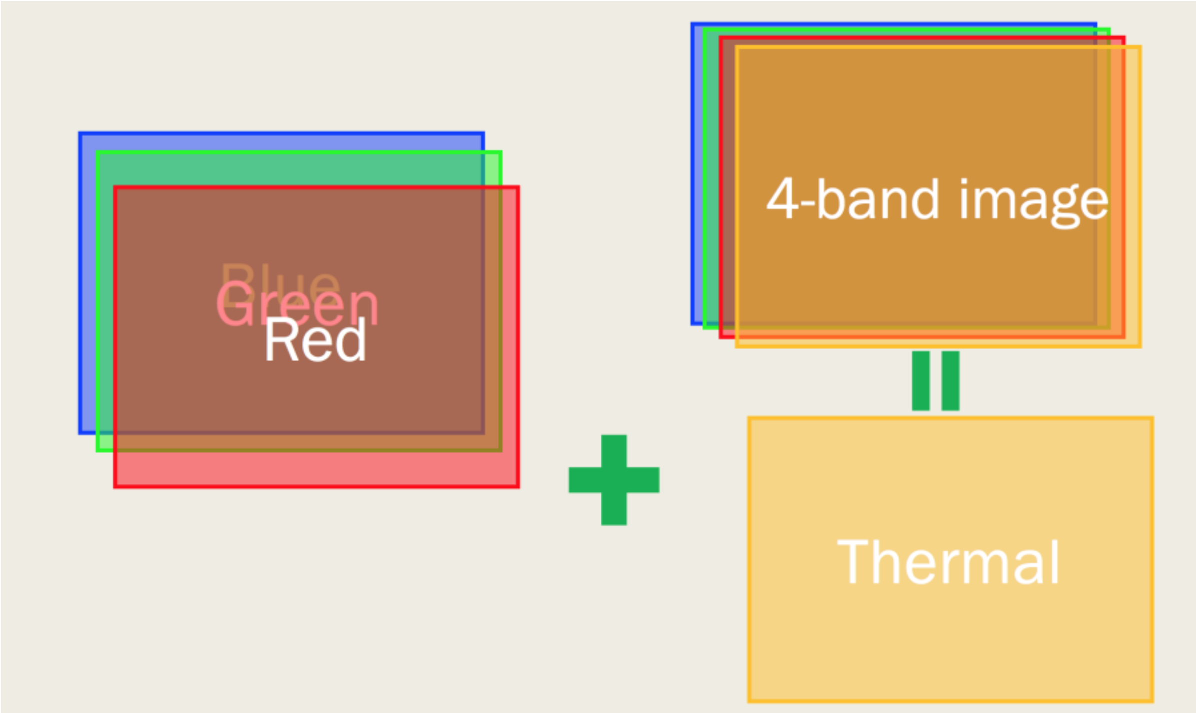


Figure. Overview

METHODOLOGY

2. Study area

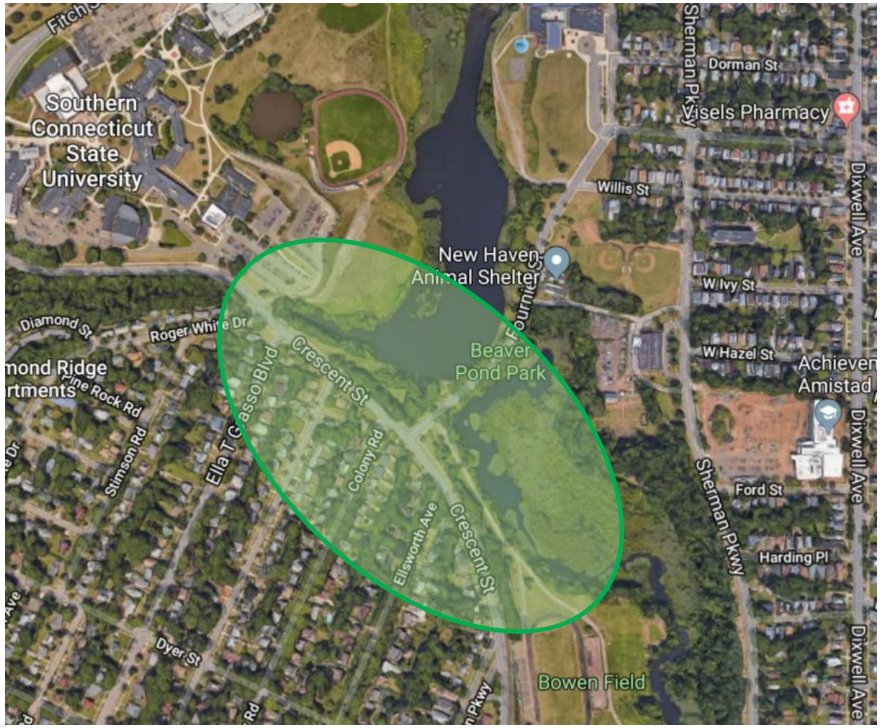


Figure. The satellite map of Beaver Pond Park (41.329522, -72.941263), New Haven, CT 06511. The green area is approximately where we did the UAV flight mission.

METHODOLOGY

3. Instrument & flight

10 min flight in Beaver Pond Park.

(a)

(b)

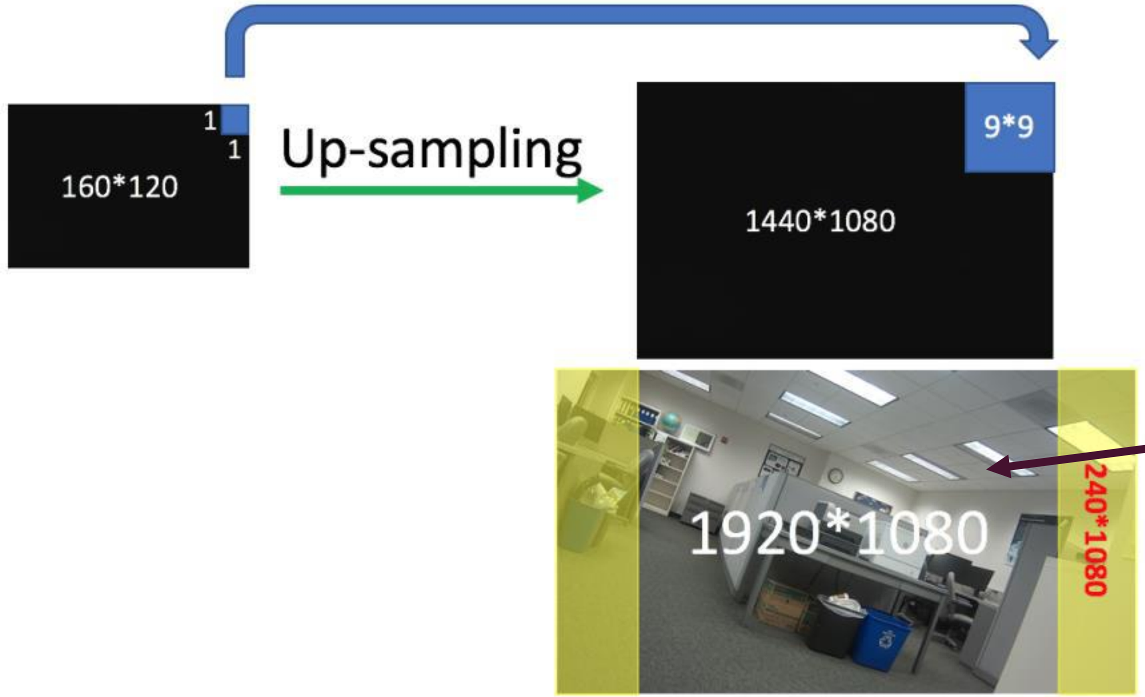
Synchronized visible and thermal images, 1pic/s. 440 images collected.

Figure. The (a) DJI Phantom 4 Quadcopter and (b) Flir DUO R dual-sensor thermal camera, which has the resolution 1920 by 1080 for visible lens and 160 by 120 for thermal lens.

METHODOLOGY

4. The workflow of Four-band Thermal Mosaicking

Batch processing
in MATLAB 2017b



From 8-bit (0-255) JPG
to 16-bit (0-65535) TIFF.
Stretching multiplier: 10

Figure. Up-sampling the coarse thermal image and cropping the same size of edges from the visible image.

METHODOLOGY

4. Running SfM algorithm in Pix4D

Bands:

	Enabled	Name	Central Wave Length [nm]	Band Width [nm]	Weight
1	☑	Red	660.0	0.0	0.2126
2	☑	Green	550.0	0.0	0.7152
3	☑	Blue	470.0	0.0	0.0722
4	☑	IR	1000.0	0.0	0.0000

Camera Model Parameters

Clear | Estimate from EXIF | Load Optimized Parameters

Warning: Wrong parameters can cause failure in the reconstruction. Read the Help for more information.

Perspective Lens | Fisheye Lens | Shutter Model: Global Shutter or Fast Readout

Image Width [pixel]:	1920	Sensor Width [mm]:	36
Image Height [pixel]:	1080	Sensor Height [mm]:	20.25
		Pixel Size [µm]:	18.75
Focal Length [pixel]:	1498.67	Focal Length [mm]:	28.1
Principal Point x [pixel]:	960	Principal Point x [mm]:	18
Principal Point y [pixel]:	540	Principal Point y [mm]:	10.125

Figure. In-APP settings.

Check in EXIFTOOL

METHODOLOGY

Sparse Point Cloud

↓

Dense Point Cloud

↓

Mesh to 3D Model

↓

Orthomosaic & DSM

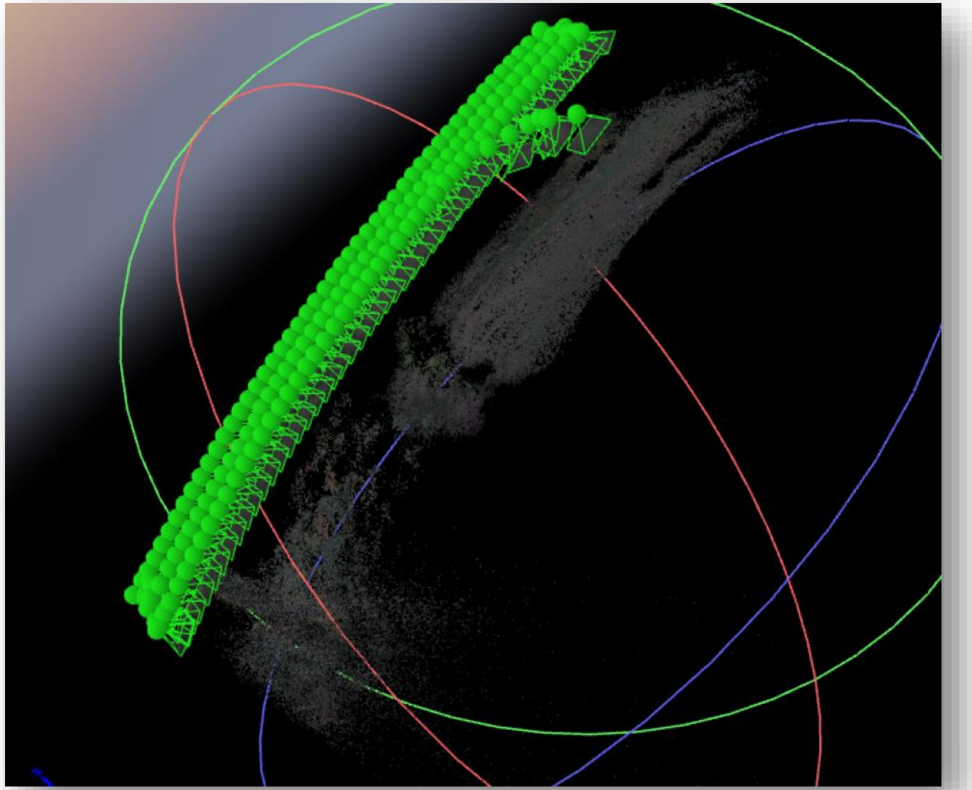


Figure. In-APP settings.

METHODOLOGY

5. Results

- ❑Identical pixel size
- ❑Identical image dimension
- ❑Identical sampled area
- ❑Allows pixel-by-pixel analyses

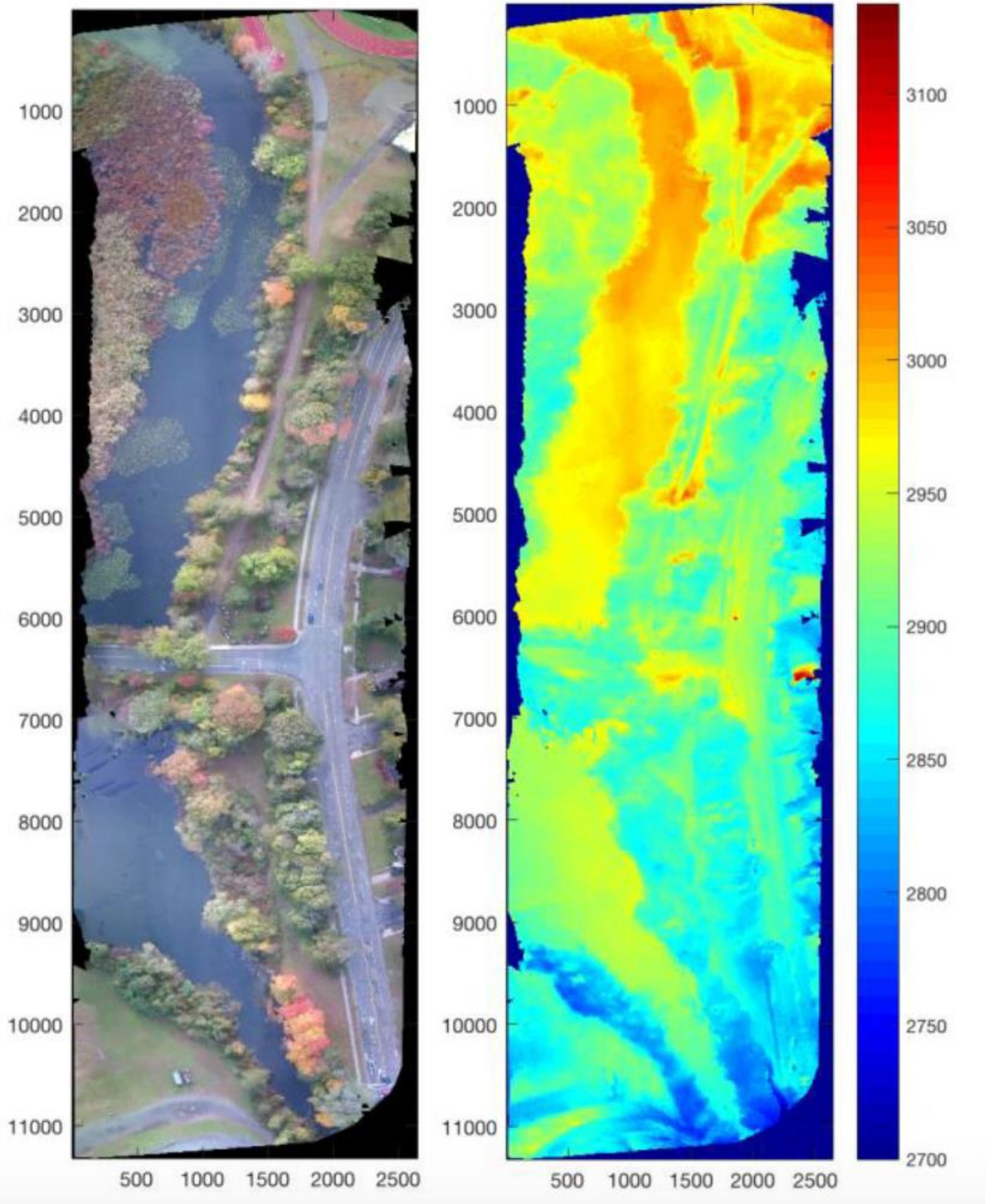


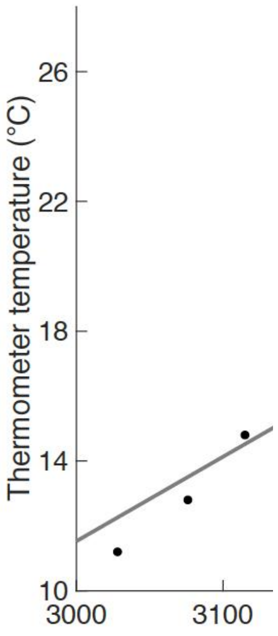
Figure. Visible orthomosaic and thermal orthomosaic

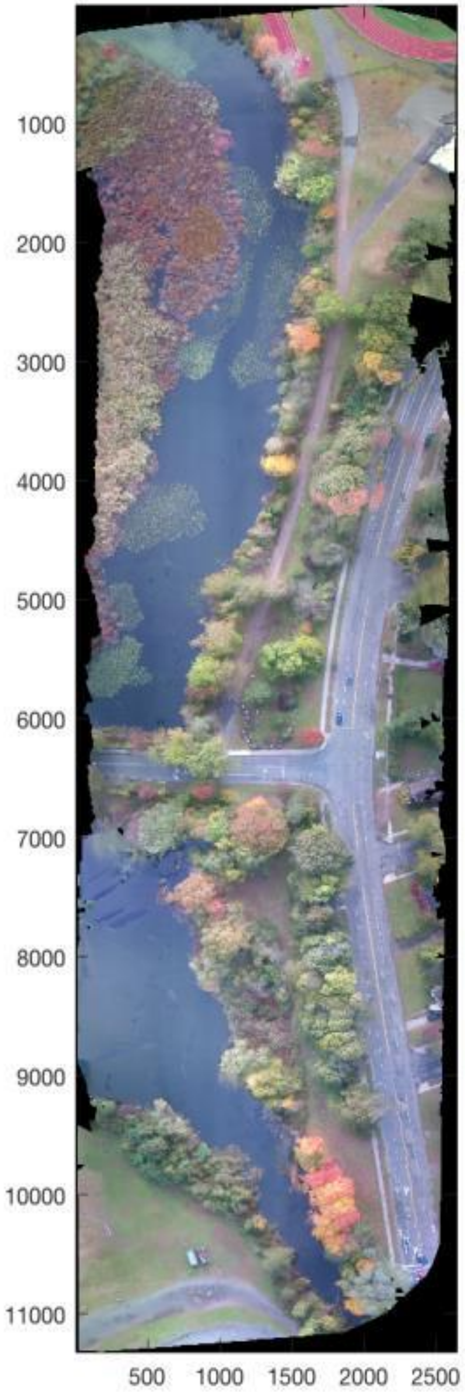
CALIBRATION

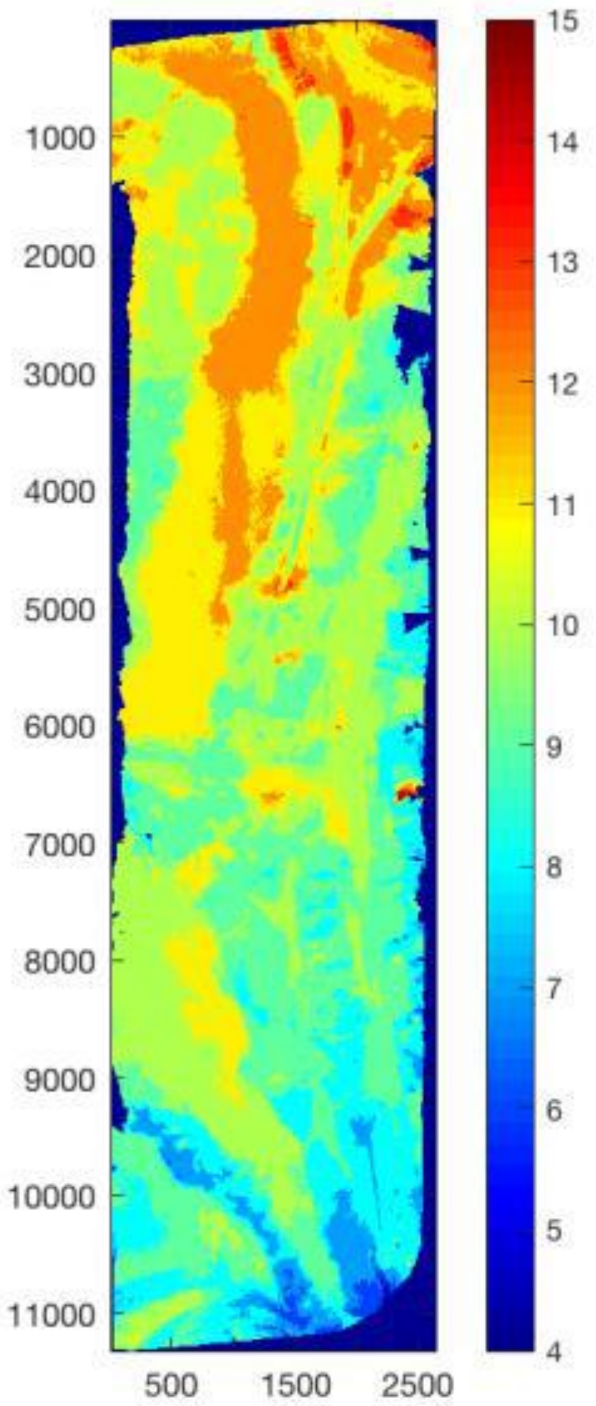
1. Radiometric calibration: synchronous measurement

Figure. Synchronous measurement: (a) is the themometer we used, and (b) is the visible image that has captured the “action” of measurement.

1. Radiometric … nt







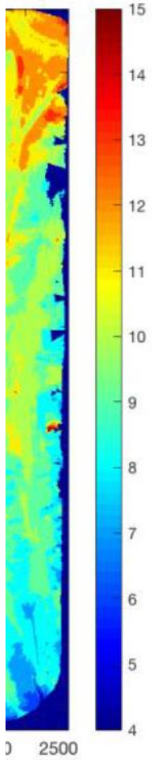


Figure. Linear regressio … dicted temperature map

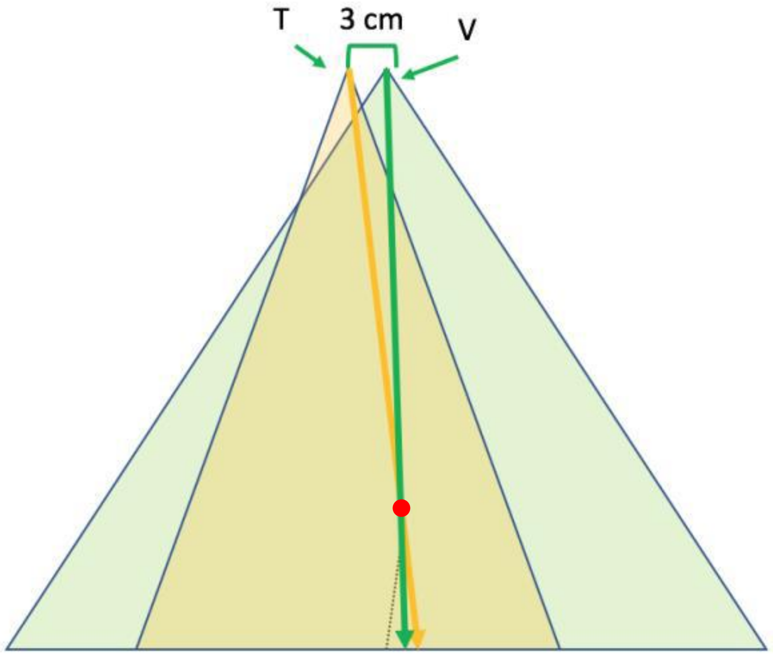
CALIBRATION

2. Position calibration: source of error

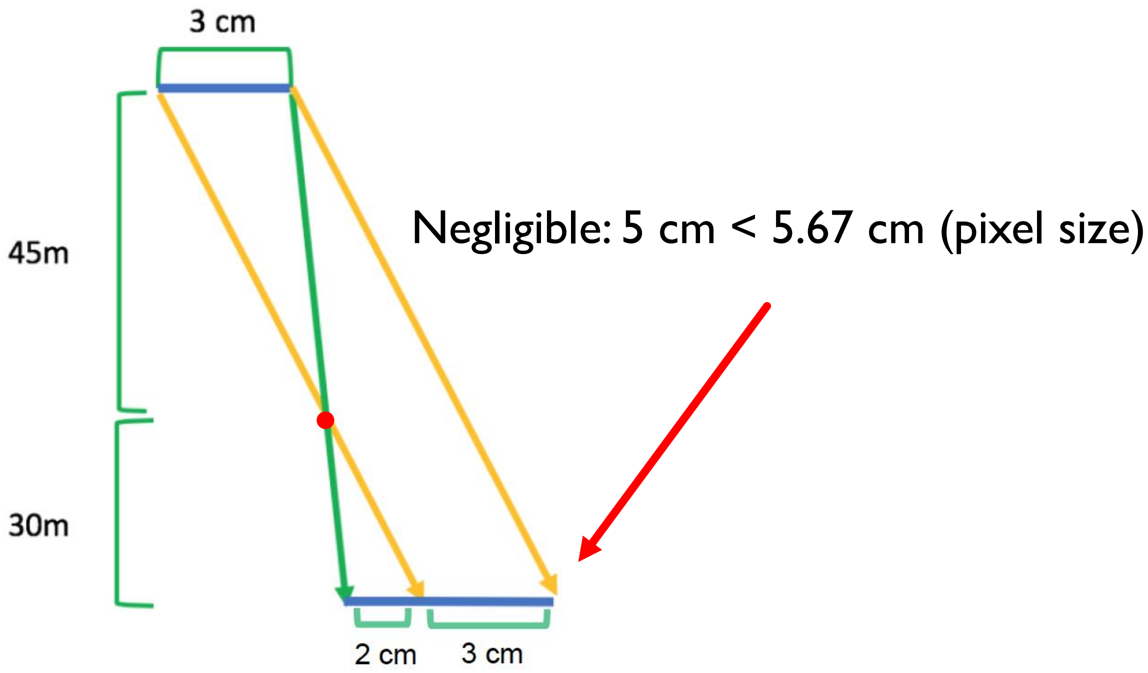
- ❑ The visible lens is about 3 cm away from the thermal lens so they actually cover different area, but we still registered the images by midline.
- ❑ There should be shutter delay between the lenses, although they are almost synchronized. The delay will lead to misalignment in different directions as the UAV was moving back and forth.
- ❑ Other misalignment due to systematic error.

CALIBRATION

2.1. Misalignment caused by lens distance



(a)



(b)

Figure. (a) The green triangle is the FOV of visible lens represented by “V”, with the green arrow as its sight line. The yellow triangle is the FOV of thermal lens represented by “T”, with the yellow arrow as its sight line. (b) The total misalignment of a 30 m high object on the base map.

2.2. Obje

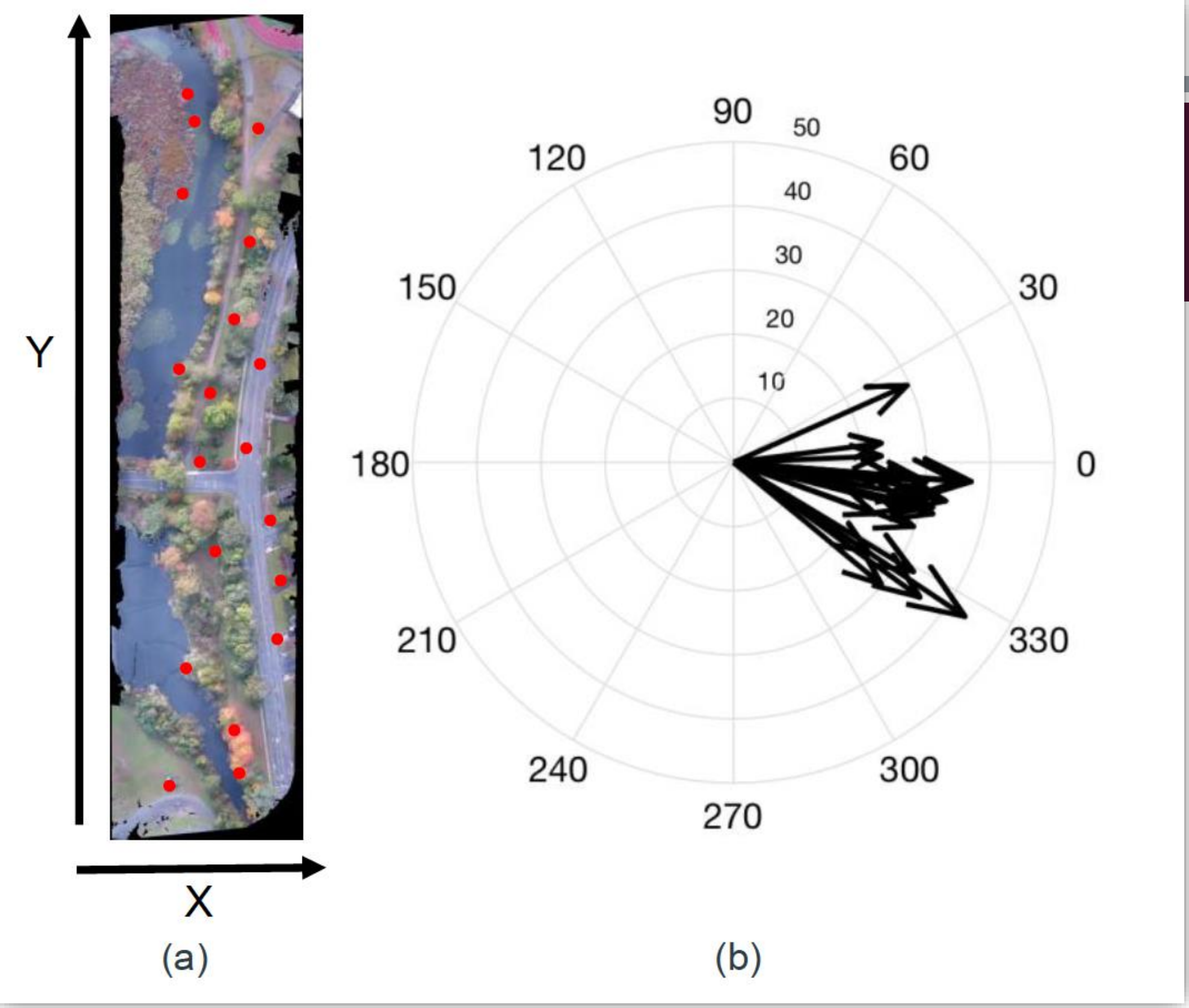
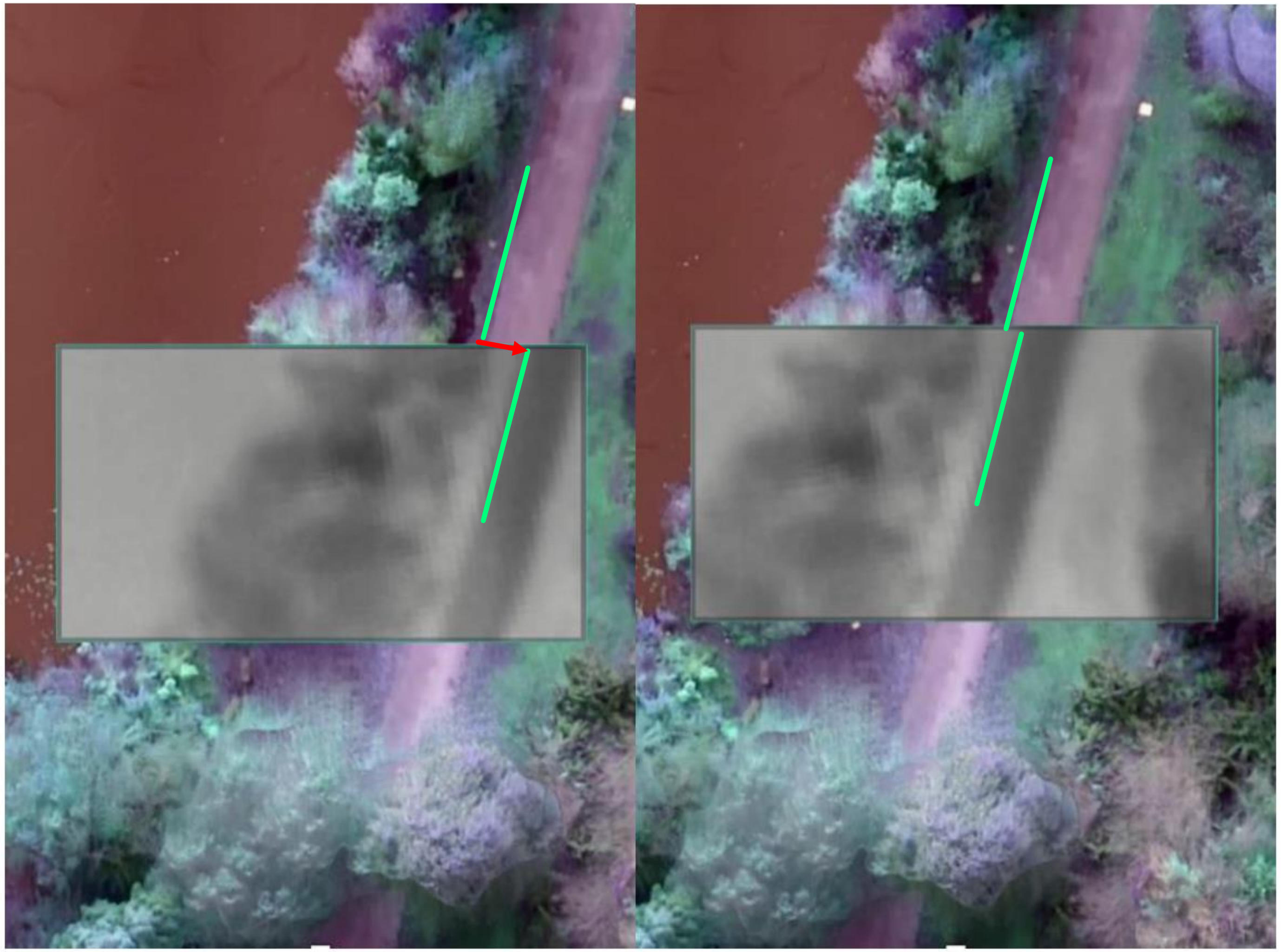


Figure. Visualizing the object-based calibration



(a) (b)

Figure. The linked view in ENVI to show the consistency of thermal orthomosaic and visible orthomosaic: (a) The misalignment before the object-based calibration. (b) The misalignment after the object-based calibration.

1.Val

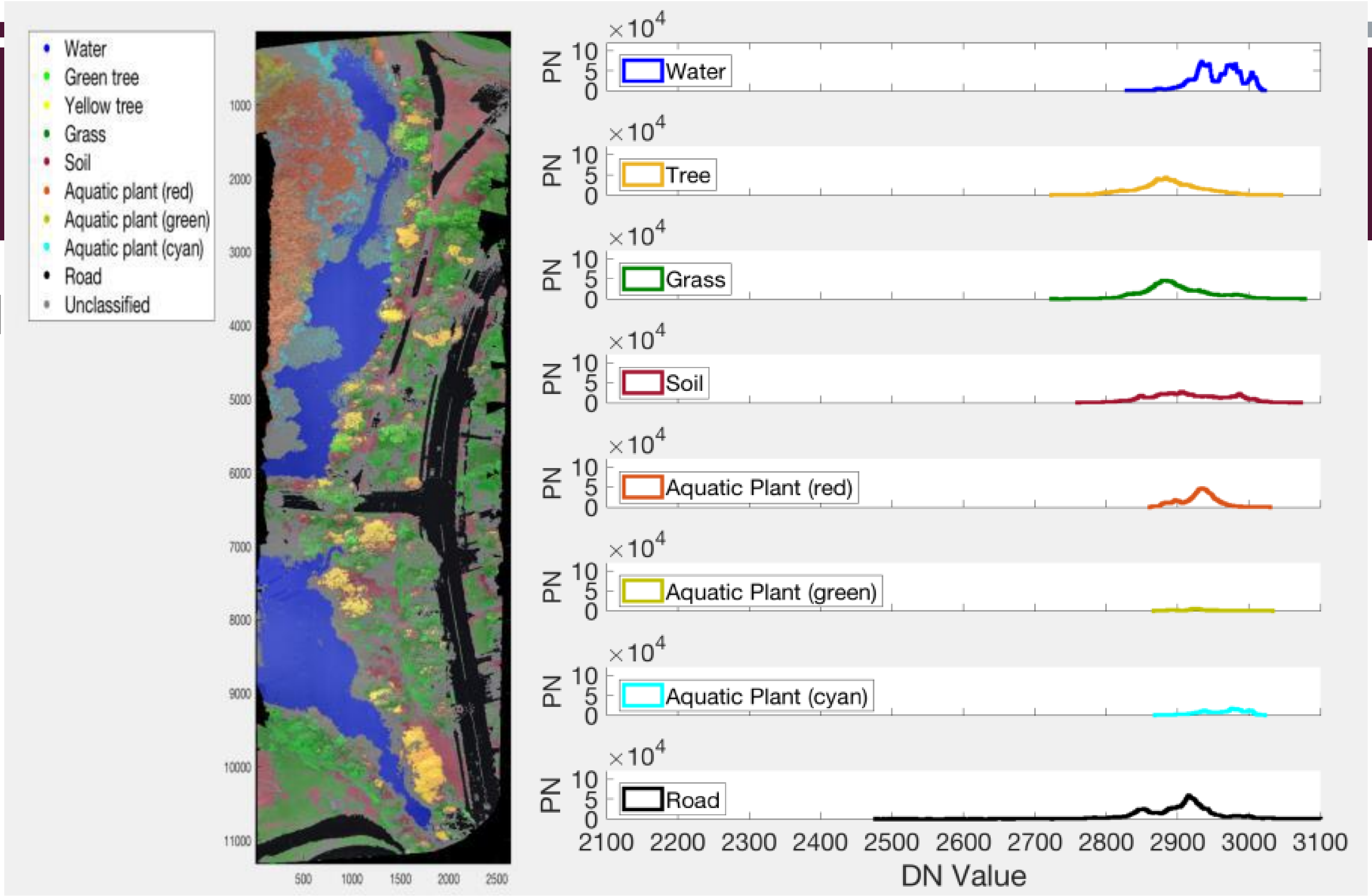


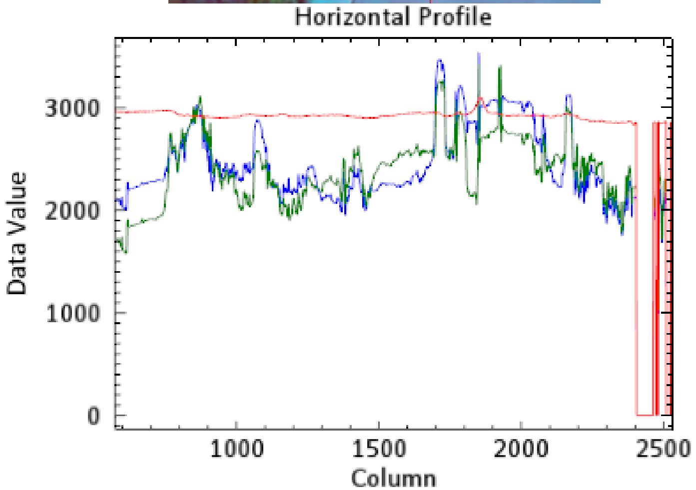
Figure.13 The rule-based classification of the visible orthomosaic (left part) and the histograms of corresponding clusters (right part) in thermal band.

VALIDATION

1. Validating the object-based calibration

(a)

(b)



(c)

Transect	Horizontal	Vertical	Main-diagonal	Anti-diagonal
T1	-25	-26	-18	18
T2	-5	-4	0	21
T3	-5	19	-16	-7
T4	-4	4	-5	4
T5	4	-2	11	3
T6	1	-7	3	3
T7	0	-2	-2	-7
T8	1	9	0	0
T9	6	-18	3	-3
T10	4	-6	9	-6
RMS	8.72	12.52	9.10	9.71

CONCLUSION

- The Four-band Thermal Mosaicking is proved to be a reliable method to bypass the difficulty of mosaicking single-band thermal imagery.
- The generated thermal orthomosaic has exactly the same resolution and sampled area compared to the visible orthomosaic. Therefore, the Four-band Thermal Mosaicking make it possible to do pixel-by-pixel analysis between orthomosaics.
- Via cluster analysis, we validated that the temperature map can reflect the difference in thermal property. The object-based calibration is an effective method to minimize the misalignment regardless of the error source.

The future work should focus on: (1) more rigorous radiometric calibration, in which the difference between emissivity of the objects should be considered. (2) quantification of the position error caused by shutter delay. (3) more solid validation of thermal representativeness.

Thank You!